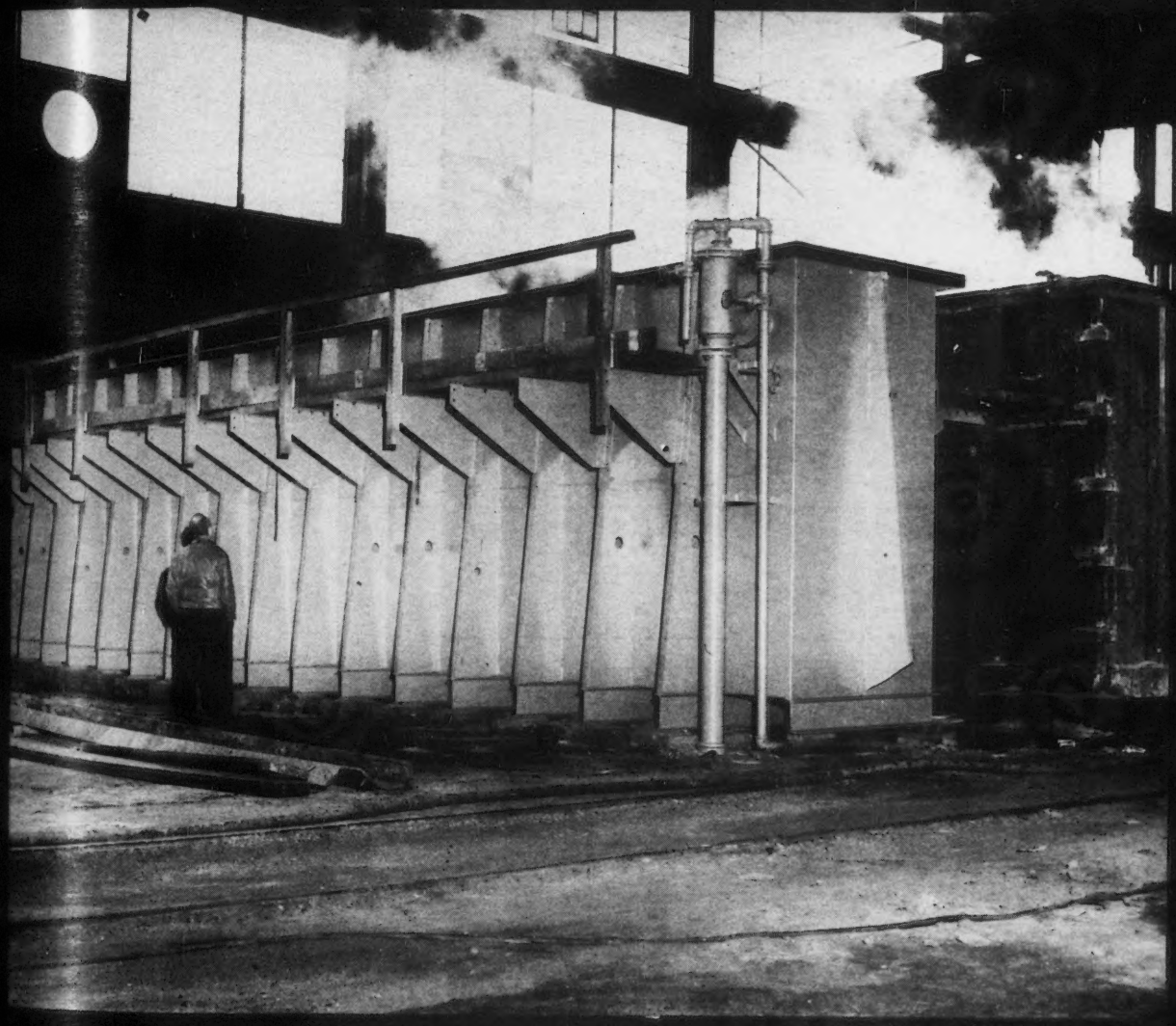
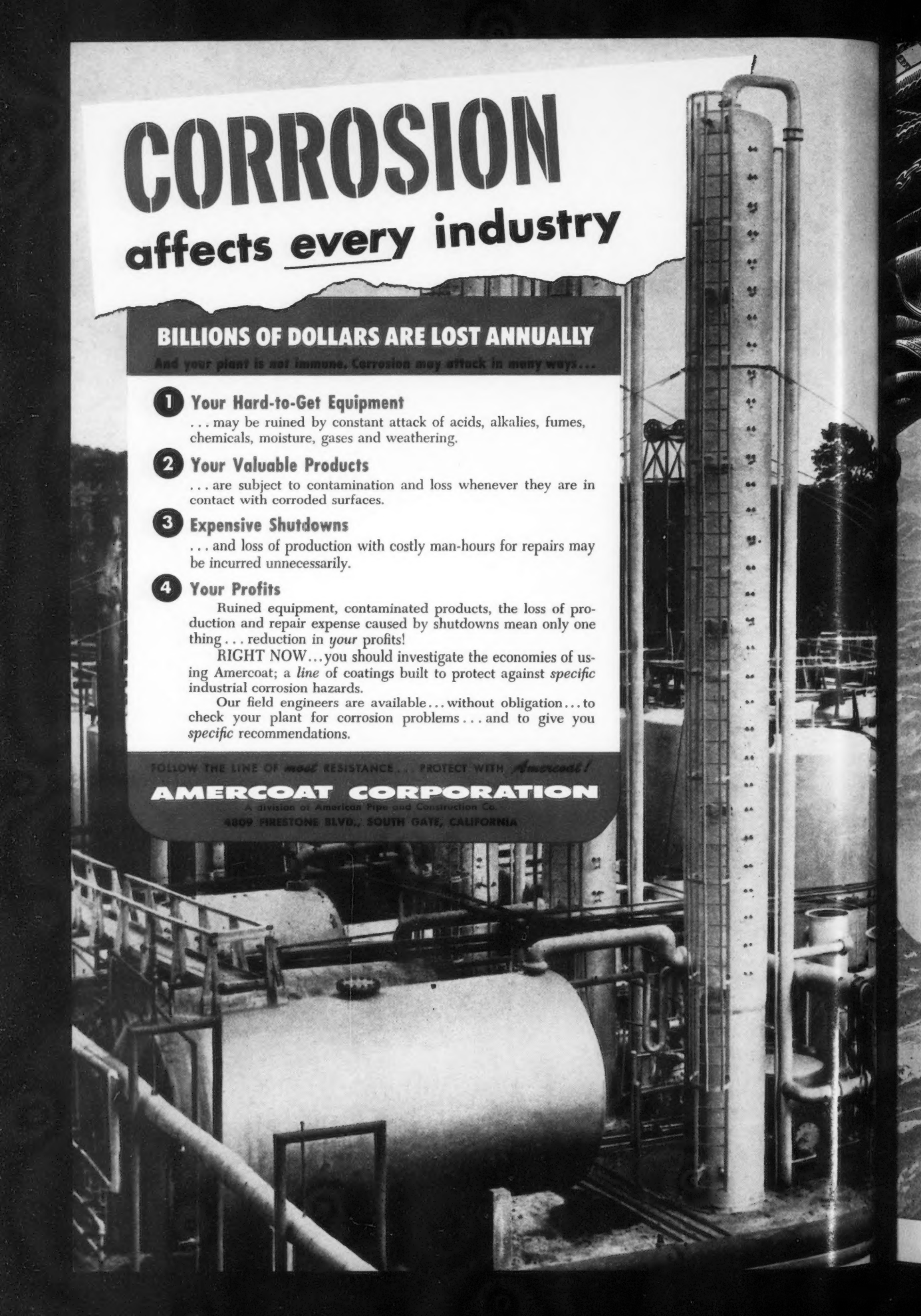
Corrosion




CORROSION
affects every industry
BILLIONS OF DOLLARS ARE LOST ANNUALLY
And your plant is not immune. Corrosion may attack in many ways...
1 Your Hard-to-Get Equipment
... may be ruined by constant attack of acids, alkalies, fumes, chemicals, moisture, gases and weathering.
2 Your Valuable Products
... are subject to contamination and loss whenever they are in contact with corroded surfaces.
3 Expensive Shutdowns
... and loss of production with costly man-hours for repairs may be incurred unnecessarily.
4 Your Profits
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FOLLOW THE LINE OF most RESISTANCE... PROTECT WITH Amercoat!
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This bolted bonnet type Y valve, made to special order in a wide range of alloys, is especially engineered for severe corrosive service. Like all ALOYCO valves, its dependable performance results from: metallurgical research devoted exclusively to corrosive applications . . . foundry and machine shop facilities set up for high alloy valves *only* . . . casting and machining practices dictated by the difficult characteristics of the alloys required for corrosive services.

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Our *Aloyco Corrosion Clinic* is available to you for "diagnosis" and "treatment" of problems relating to valves in corrosive service. If product contamination or excessive valve replacement is costing you money, take advantage of the *Aloyco Corrosion Clinic's* expert consultation and engineering service.

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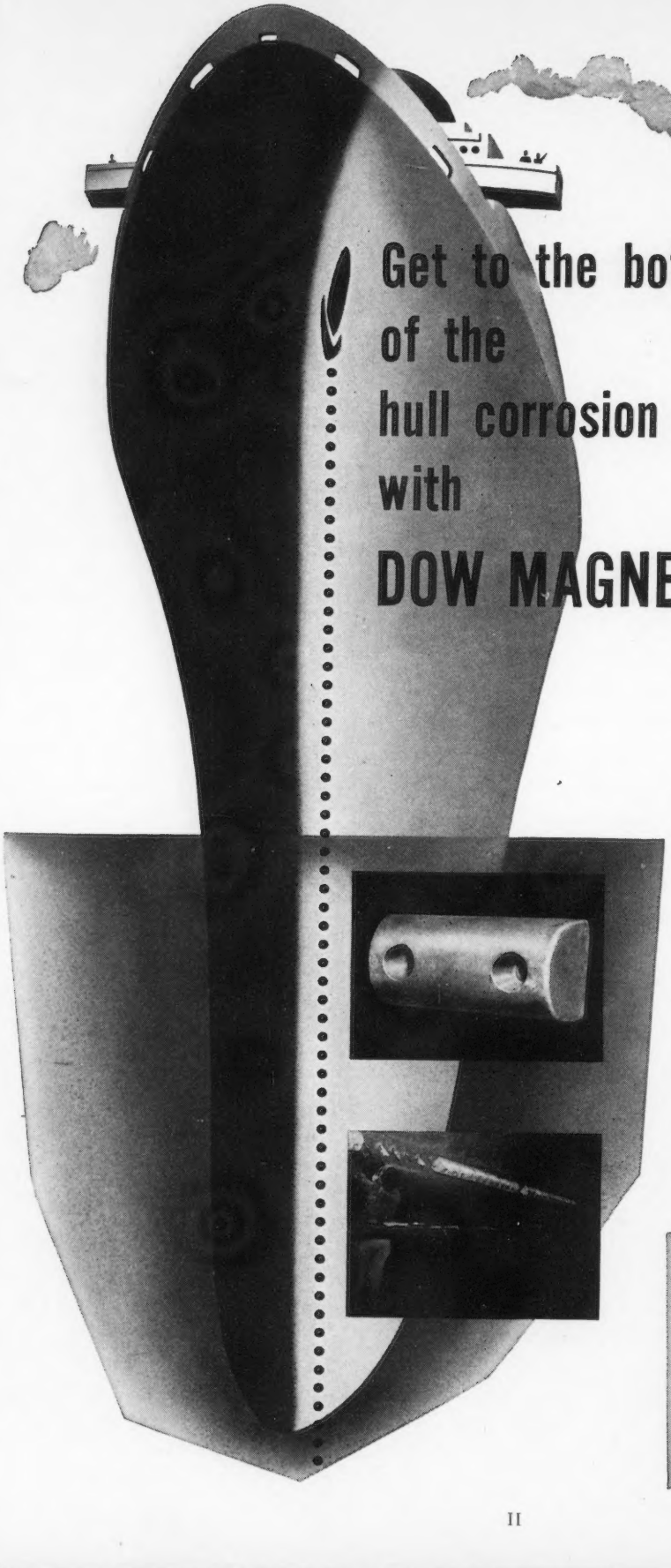
1st in Corrosive Service



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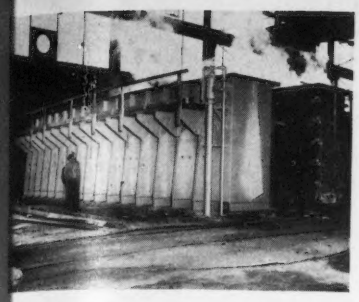

THIS MONTH'S COVER—This sulfuric acid pickling tank, lined with Goodrich Triflex sheet rubber and sheathed with two courses of acid resistant brick was sandblasted and sprayed with four coats of Amercoat vinyl plastic coating by Metalweld, Inc. to prevent corrosion from fumes and spillage. Pickling tanks provide among the most severe tests for anti-corrosion materials.

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devoted entirely to
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research and control

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- **Authors of technical papers on corrosion are invited to submit titles and abstracts of papers to appropriate officials of the Technical Program for the 1953 Chicago Conference of the National Association of Corrosion Engineers, to be held March 16-20.**
- **Information on symposia titles and the names of symposia chairmen named to date will be found in the News Section of this issue of Corrosion.**
- **The Association also welcomes at any time constructive discussions of its technical material and technical papers on corrosion for publication in Corrosion.**
- **Interested authors may secure on request a copy of the "NACE Guide for the Preparation and Presentation of Papers" which describes the Association's customs and needs more fully.**

TYGON

Versus NH_4OH

AMMONIUM HYDROXIDE, ammonium salts, ammonia liquors and ammonia gas have many uses. They likewise have many opportunities to cause considerable damage to plants and equipment. However, maximum use with minimum corrosion can be made of ammonia and its various compounds through the proper use of the versatile TYGON in its several forms.

The TYGON family of plastic compounds consists of a series of selected polyvinyl resins which are skillfully modified with other materials to exhibit the maximum in chemical resistance and general physical properties. In its various forms, TYGON finds many uses in many plants in many industries.

As a calendered or press-polished sheet, TYGON is primarily used as a lining or covering in equipment such as tanks, towers, reactors, vats, drums, hoppers, bins, blowers, impellers, fume hoods and fume ducts. Large amounts are also die-cut into gaskets for use as positive, enduring seals in all types of process equipment.

In the form of sheeting, TYGON resists all concentrations of ammonium hydroxide at temperatures ranging up to 160 °F. When subject only to ammonia fumes, the temperature limit can be raised to about 200 °F. Higher service temperatures are possible with a corrosion-resistant brick sheathing over the TYGON lining. On prolonged exposure to ammonium hydroxide, TYGON exhibits a slight hardening and change in color. However, its protectability is unaffected.

When used as gasketing, TYGON has the same resistance to NH_4OH as it does in sheet form. Temperature limits are higher with the maximum depending on the size, design, and manner of use of the gasket.

As an extrusion, TYGON is most widely used as tubing or piping. However, extruded solid cord, or channel, are also used as a gasketing, expansion jointing, or packing. In these forms, TYGON resists ammonium hydroxide in any concentration and at temperatures up to 160 °F. A slight stiffening and color change in the extruded TYGON may be noted with prolonged contact, but this does not affect its resistance.

TYGON Tubing has proved its worth in many laboratory and plant uses. Its glass-like clarity, full flexibility, smooth surfaces, light weight, high strength and long life make TYGON ideally suited to the fast, simple, safe transmission of virtually any liquid, gas, or semi-solid. The larger sizes, up to 2″ ID, can be used to advantage as temporary or permanent transfer lines, as flexible connections and line desurgers, as syphon hoses, as oil and compressed air lines, and as inlet and outlet ports on pumps and filters. For pressure applications exceeding a constant head of 40 psi, particularly at elevated temperatures, braided jacket reinforcement is available and suggested.

As molded goods, TYGON exhibits the same resistance to NH_4OH as the extruded form. Specific pressure and temperature limits depend on the size and design of the piece. Typical molded TYGON items include gaskets, grommets, washers, closures, handles, bumpers and many other parts and fittings.

As a paint, TYGON usually sees service as a protective maintenance coating. As such the physical limits of a thin film must be realized. TYGON Paint protects plant and equipment against the fumes, spillage, or condensate of ammonium hydroxide in any concentration and at temperatures as high as 200 °F. Prolonged immersion, however, is not advised without the counsel of U. S. Stoneware engineers. For mild environments a primer and no less than two top coats should be used. For severe exposures a minimum of five coats plus primer is advised.

As a plastisol (TYGOFLEX), TYGON finds use as a heavy duty coating and in the casting or "slush" molding of flexible parts and fittings. It resists NH_4OH in all concentrations. Temperature limits depend on the thickness of the coating deposited.

In any of its forms, TYGON is low cost insurance against the attack of not only ammonium hydroxide and related chemicals, but a wide range of other alkalies, acids, oils, greases, and water. For best results with TYGON, consultation with U. S. Stoneware engineers is recommended.

TYGON plastics

In addition to TYGON in its various forms, we also manufacture a number of other materials capable of handling ammonium hydroxide in any concentration and under all types of operating conditions. These products include chemical stoneware and porcelain acid proof brick and cements, homogenous lead linings, and other organic linings and coatings.

Why don't you submit your corrosion problem today? There's no obligation and we'll be pleased to be of assistance. So write, now! 470C

THE UNITED STATES STONEWARE CO., Akron 9, Ohio

ENGINEERS, MANUFACTURERS, ERECTORS OF CORROSION-RESISTANT EQUIPMENT SINCE 1865

55 gallon, 12 gauge solid Nickel shipping and storage drums built to I.C.C. Specification 5K.

How to lower shipping costs on highly corrosive chemicals

Are you concerned with the shipping and storage of dangerous and corrosive chemicals?

Then you'll find these five advantages of Nickel and Nickel Alloy drums of interest . . . *and profitable!*

LIGHT WEIGHT. Nickel and Nickel Alloy drums often cut to ⅓ the tare weight of shipping and storage containers. They save on manpower and on shipping and handling costs without reducing volume.

CORROSION-RESISTING. These drums do not chip or peel. Their resistance to corrosion reduces metal pickup, helps maintain product purity, eliminates need for corrosion inhibitors.

STRONG. High mechanical strength and toughness mean Nickel and Nickel Alloy drums do not crack or break open despite rough handling.

DURABLE. Nickel and Nickel Alloy drums give years of trouble-free service. And should minor damage occur, they are easy to repair by welding, brazing or soldering methods.

I.C.C. ACCEPTED. Many corrosives are at present being handled with I.C.C. approval. A partial listing includes: Monel® drums (I.C.C. Specification 5M) liquid bromine and hydrocyanic acid; Solid Nickel drums (I.C.C.–5K) acetyl, benzyl, benzoyl, thiophosphoryl, pyrosulfuryl, and thionyl chlorides, as well as phosphorus trichloride and phosphorus oxychloride.

Perhaps you have other corrosives for which I.C.C. specifications are not yet established. Now is the time for you to investigate Nickel and Nickel Alloy drums so that you can have I.C.C. acceptance when these drums again become available for extensive use. Write for full information, today.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street, New York 5, N. Y.

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MONEL® • "R"® MONEL • "K"® MONEL
"KR"® MONEL • "S"® MONEL • NICKEL
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TECHNICAL PRACTICES COMMITTEES' DIRECTORY

(Continued from Page viii)

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The Role of Oxygen in Corrosion and Cathodic Protection
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Designs by R. P. Howell.

Corrosion Control in Gas Lift Wells
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Lapel Pins

Approx. Size

Approximately 7/16 inches high, gold, inlaid with bright red enamel background to "NACE" and deep blue enamel background to words "CORROSION CONTROL." Ruby center.

For Association Members Only

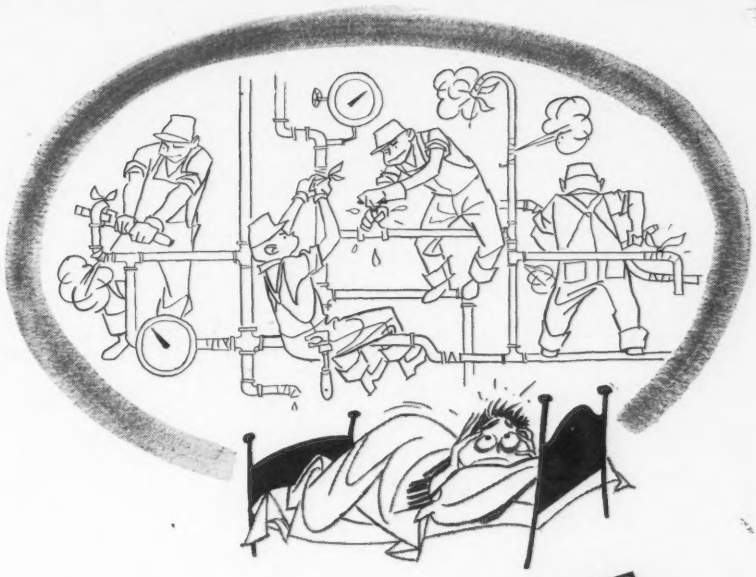
$7

Address Orders to
A. B. Campbell, Executive Secretary

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg., Houston 2, Texas

Say goodbye to nightmares about pipe repairs and replacements!



Install corrosion-resistant saran lined steel pipe wherever you are piping chemicals and solvents. Because saran is extremely resistant to most chemicals and solvents, such installations will give dependable, long-term service and reduce shut-downs due to pipe repairs and replacements. In addition to minimum maintenance cost saran lined steel pipe brings you another important advantage: it is easily field fabricated. No intricate tools required, no waiting for special fabrication, no costly delays. *Saran lined steel pipe is manufactured by The Dow Chemical Company.*

install corrosion resistant **SARAN LINED** steel pipe

Write to the Distributor:

SARAN LINED PIPE COMPANY

2415 BURDETTE AVENUE • FERNDALE, MICHIGAN

Offices in: New York • Boston • Pittsburgh • Tulsa Philadelphia • Chicago • Portland • Indianapolis • San Francisco • Houston • Denver • Los Angeles • Seattle Cleveland • Charleston, S. C. • Toronto • Montreal

RELATED PRODUCTS

Saran rubber tank lining—an outstanding lining where resistance to grease, many solvents, acids and other chemicals is indicated.

Saran rubber molded parts—stoppers, diaphragms, various-sized moldings for valves, instruments, etc.

clip and send today!

Saran Lined Pipe Company,
2415 Burdette Avenue, Ferndale, Michigan
Please send me a copy of your catalog on Saran Lined Pipe, Valves and Fittings.

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SARAN LINED PIPE a DOW product

You can't stop a raging fire with a garden hose

You can't stop corrosion with ordinary paints . . .

it takes BITUMASTIC COATINGS!

CORROSION can't be stopped by ordinary paints or conventional protective coatings . . . they can't protect surfaces against the ravages of rust for any appreciable length of time.

But Bitumastic Coatings can!

FIRST—Unlike maintenance paints, Bitumastic® Protective Coatings are specially formulated from a base* of coal-tar pitch that is, for all practical purposes, impervious to water. When you keep moisture away from an exposed surface, you *stop* corrosion.

FURTHER—Bitumastic Coatings provide an extra-tough, extra-thick barrier against corrosive elements—a barrier that is impenetrable. And these coatings provide up to 8 times the film thickness of conventional paint coatings.

FINALLY—Bitumastic Coatings stop corrosion caused by moisture—acid fumes—alkaline fumes—corrosive soil—salt air—heat.

There are 6 Koppers Coatings—formulated to control corrosion of metal and deterioration of concrete. Use the coupon for full information.

****Hi-Heat Gray contains a metallic base.***

SEND FOR SET OF FREE BOOKLETS!

Koppers Company, Inc., Tar Products Division
Dept. 804-T, Pittsburgh 19, Pa.

Please send me, without charge or obligation, your booklets on corrosion prevention.

Name.....

Address.....

City.....Zone....State.....

KOPPERS BITUMASTIC PROTECTIVE COATINGS

REG. U.S. PAT. OFF.

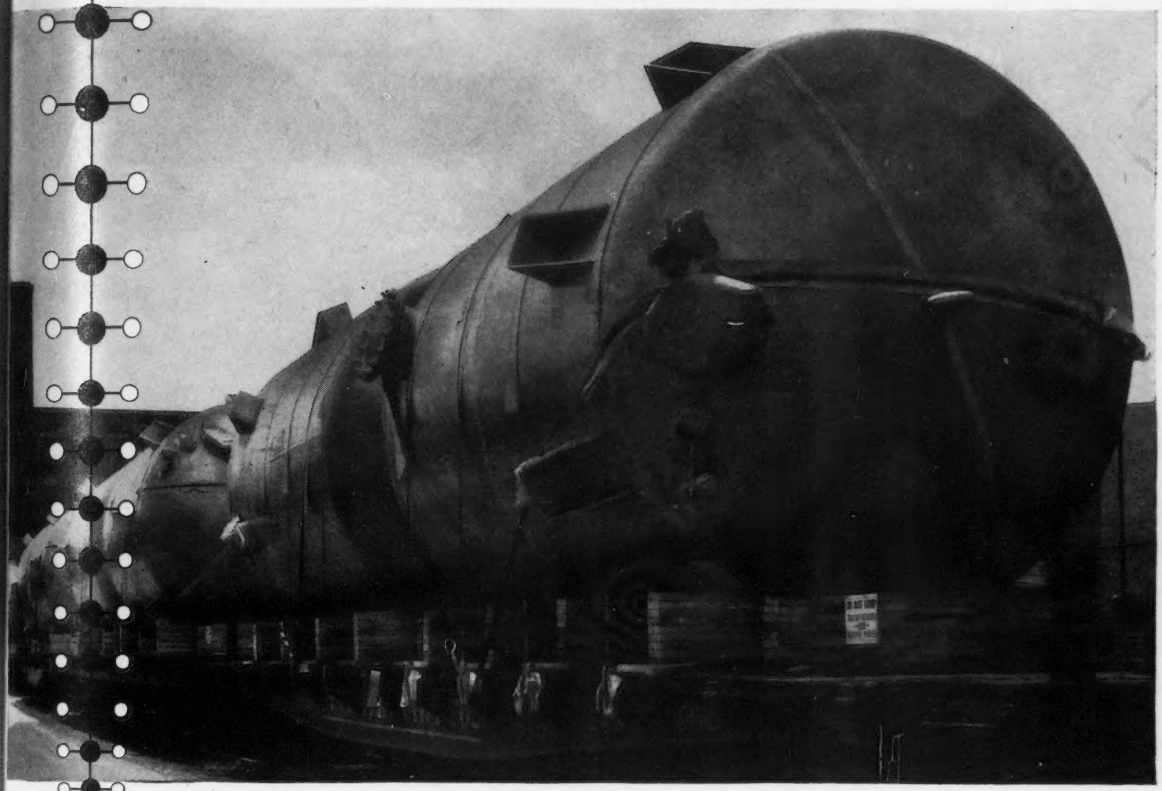
SOLD THROUGH INDUSTRIAL DISTRIBUTORS

KOPPERS COMPANY, INC., Tar Products Division, Dept. 804-T, Pittsburgh 19, Pa.

DISTRICT OFFICES: BOSTON, CHICAGO, LOS ANGELES, NEW YORK, PITTSBURGH, AND WOODWARD, ALA.

IT WON'T BOTHER fatty acids

AND VICE VERSA



The use of aluminum equipment in the processing of fats, fatty acids and aldehydes shouldn't surprise you.

Aluminum has the advantage of not promoting oxidation of these sensitive compounds. The use of *all-aluminum* equipment from overhead condensers through to the storage and distribution of the finished product completely eliminates the problem of dissimilar metals which actually accelerate oxidation.

Aluminum does more. More than protect the taste, odor, stability and appearance of these products. *It resists corrosion by free fatty acids in oils.* It is nonsparking. Aluminum improves temperature control of your processes through its high heat conductivity. It is easy to clean. Easy to machine, weld and handle in the shop. In other words, aluminum fabricates easily. Over competing metals (other corrosion-resistant metals), you save ½ to 5/6 in material costs alone.

Alcoa's development engineers have much experience with vessels, storage tanks, filters, exchangers, pipe and tube of aluminum for fatty acid service. They offer their immediate personal attention to your questions. Write (company letterhead, please) to:

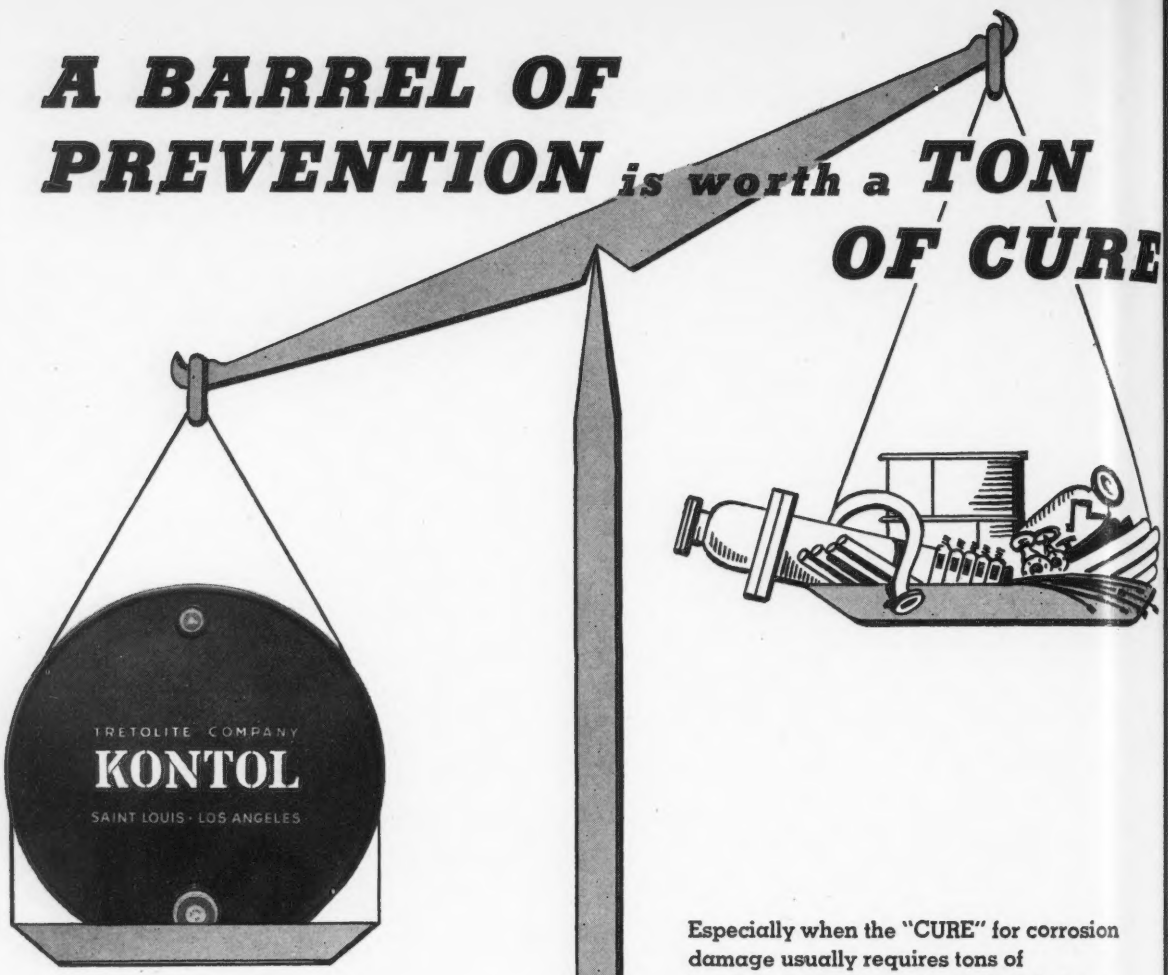
ALUMINUM COMPANY OF AMERICA
1856-H Gulf Building • Pittsburgh 19, Pa.

ALCOA ®

Aluminum resists corrosion by free fatty acids in oil

ALCOA *first in* **ALUMINUM**

A BARREL OF PREVENTION is worth a TON OF CURE



Especially when the "CURE" for corrosion damage usually requires tons of hard-to-get steel to replace corroded-out production or refinery equipment.

KONTOL inhibitors prevent corrosion damage by forming a tightly-adsorbed, impervious film at metal surfaces. This Kontol film effectively protects pumps, rods, tubing and flow lines in the field and is being successfully applied in refineries to combat severe corrosion problems. If you have corrosion troubles, get in touch with your Tretolite field engineer, today.

TRETOLITE COMPANY

St. Louis 19, Missouri • Los Angeles 22, California

CORROSION INHIBITING • DEHYDRATING • DESALTING •
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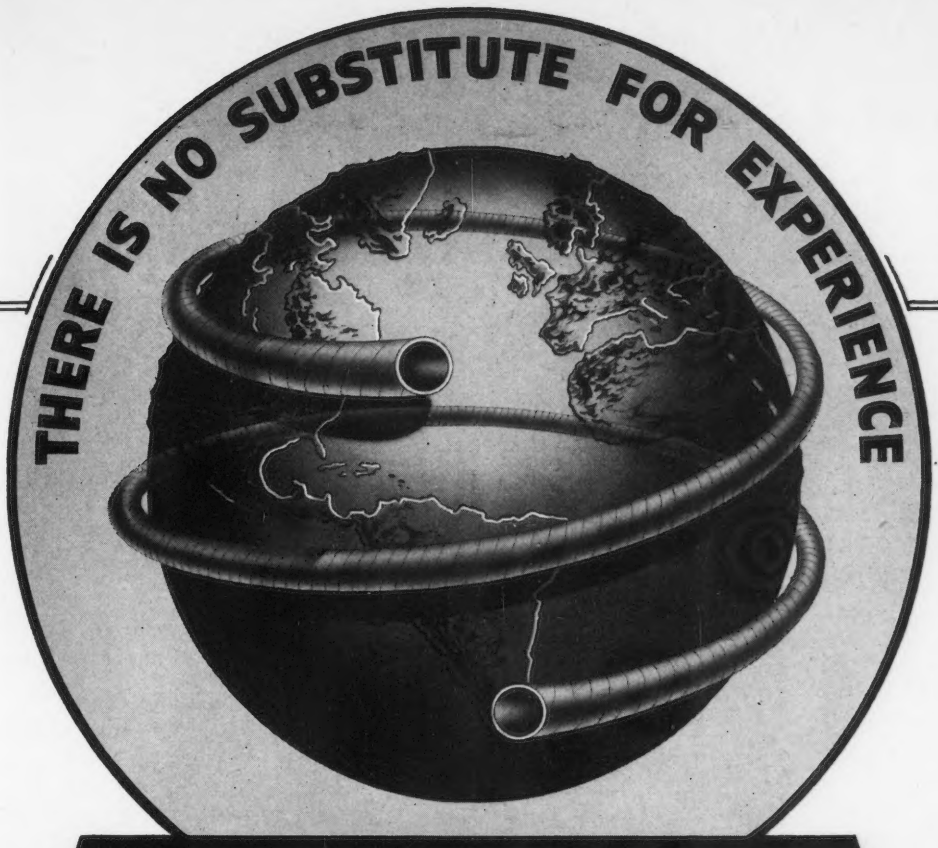
KB 52-1



"PUTTING *Permanence* IN PIPE"

CLEANING, COATING, WRAPPING & RECONDITIONING

Are you being fair to yourself and your company when you buy pipe protection on price without questioning what you're getting for ***that*** price? Our price quotations give you unquestionable work backed by more than 25 years' experience, modern equipment and plant manned by skilled craftsmen, a 56-acre pipe yard on which more than 300 million feet of pipe (½" to 60") has been coated and wrapped to the entire satisfaction of the customers. This record is hard to match.

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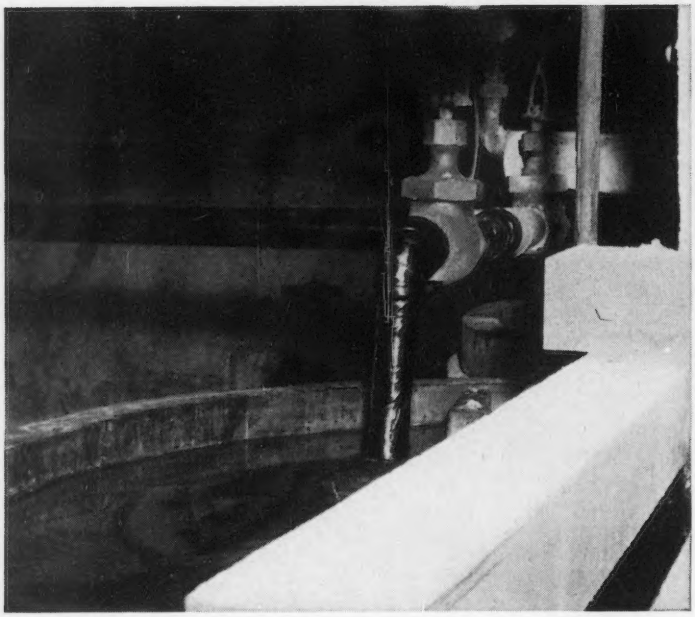
1150 McCarty **HOUSTON, TEXAS** OR chard 7566

Stop COSTLY DOWN TIME with Polyken Protective Coatings



LONGER PIPE LIFE is assured by this Polyken protective coating which safeguards piping from fumes or direct contact with acid solution in this large vat. Results: Stabilized production, lower plant maintenance.

HIGH-SPEED APPLICATION. Applying Polyken protective tape coatings, either by hand or by machine, is a fast, one-step process requiring no heat, liquids, expensive machinery or clean-up time.

DOWN TIME JUST AHEAD. View of exposed and covered pipes shows how corrosion can halt production. Note condition of old-fashioned coatings.

Polyethylene Tape Coating Applied Quickly, Easily in One Step

This Chicago plant, plagued by corrosion from acid-spray and overflow, was faced with frequent pipe replacement and—even more costly—frequent and repeated down time.

After extensive testing in laboratory and plant, the manufacturer solved this problem by selecting a Polyken pressure-sensitive, corrosion-proof tape coating made from fully oriented polyethylene—a material long recognized for resistance to almost all corrosive factors.

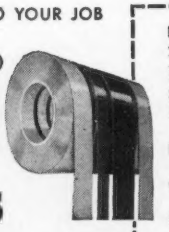
For the production-protecting answer to your corrosion problem, call on Polyken's engineering experience. Write for further data, brochure and samples of low-cost, quickly-installed Polyken protective coatings today.

Polyken No. 882

- elastic, conformable
- moisture-proof
- fungus-proof
- solvent-resistant

TAILORED TO YOUR JOB

Polyken®



INDUSTRIAL TAPES

Department of Bauer & Black
Division of The Kendall Company

Polyken, Dept. CH
222 West Adams St., Chicago 6, Ill.

Please send me specifications, samples, and further information on POLYKEN PROTECTIVE COATINGS.

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Company_____

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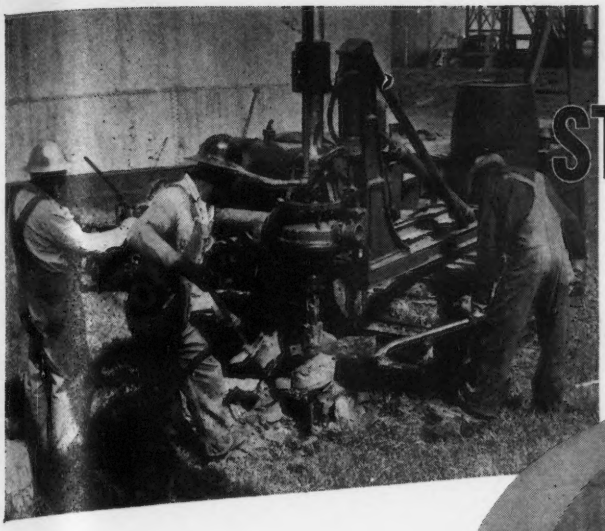

A Leading Southwestern Refinery

STOPS CORROSION

with NATIONAL TRADE-MARK

Graphite Ground Anodes

RESULTS

- Lowest *installed* cost
- 90% of corrosion leaks eliminated within 5 years of first installation
- Labor crews reduced . . . trained men kept on the job
- Power equipment requirements much lighter
- Installation simplified in congested areas
- Much lower amortization cost due to longer anode life

THIS major producer has several million square feet of uncoated tank bottoms and hundreds of miles of underground piping. Maintenance was heavy. Studies indicated cathodic protection – *but how?*

The high current necessary to give continuous, positive protection dictated the use of an impressed current system. First estimates favored scrap steel over graphite rods on a cost-per-unit basis.

But experience revealed a multitude of hidden costs and operating difficulties in the installation of steel scrap.

Scrap had to be welded. It required heavy trenching and transportation equipment . . . large labor crews. Bad weather held up men, machines and progress.

Re-evaluation clearly favored a "distributed" system of vertically-installed "National" Graphite Ground Anodes– which were specified for the whole of this large project.

WRITE FOR CATALOG SECTION S-6510

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NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
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DOLLARS AND SENSE . . . point to "Eveready" No. 1050 Industrial Flashlight Batteries . . . delivering *twice* as much usable light as any battery we've ever made before. Their unique construction prevents swelling or jamming in the case . . . has no metal can to leak or corrode.

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THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

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The Technical Practices Committee

By TED S. ZAJAC*

Shell Oil Co., New York, N. Y.

IT APPEARS from discussions with members of the National Association of Corrosion Engineers that many are not clear as to the organization, objectives, functions and activities of the Technical Practices Committee. Perhaps a general review and discussion of the subject will not only help to clarify this existing situation but might also assist in promoting further expansion of TPC activities.

The evolution and growth of TPC has been quite rapid as indicated by a brief review of its existence to date. The forebearer of TPC was the first NACE technical committee on condensate well corrosion appointed by the board of directors in 1944. The importance and significance of technical committee activities to the well-being and future growth of NACE was recognized early and in 1945 the board of directors created the Technical Committee as one of the standing committees of the Association. This committee was subsequently renamed Technical Practices Committee. In the years from 1946 to 1952 TPC has grown from a committee of three sub-committees into one of nineteen. A directory of TPC is carried prominently in each issue of Corrosion for those interested in the various subcommittees. The first chairman of TPC was R. B. Mears, who was succeeded by M. G. Fontana in 1950, and who in turn was succeeded by T. S. Zajac in 1952.

TPC's organization is generally prescribed by the Articles of Organization (Article VI, Sections 2 and 4) and the By-Laws (Article IV, Section 2) of the association. In essence these provide that TPC shall consist of ten members, the chairman shall be appointed by the NACE president and the president, vice-president and secretary shall be members ex-officio. Additionally, the chairman shall have power to appoint such subcommittees as he finds necessary or desirable, and in making such appointments, he shall not be limited, in the selection of members, to the roster of membership of the committee. Subcommittee chairmen in turn have the same appointive powers for any of their subgroups. TPC is currently composed of the nineteen subcommittee chairmen, the three ex-officio members and the chairman. Since the above broad directives are inadequate for guiding the day-to-day conduct of TPC and its subcommittees with each other, as well as with the other committees of the association and the Central office, an operating guide for this purpose is now being prepared. To promote the maintenance of an active, imaginative, constructive and continuous TPC activity, as well as to distribute the work load, a system of rotating subcommittee chairmen periodically is being instituted. A plan for maintaining active committee membership is also under study.

The objectives of TPC naturally are the same as those of the association. Since these are listed prominently in each issue of Corrosion they will not be repeated here although an invitation to review them is extended to those interested.

The functions of TPC are the following: 1) Activate new subcommittees as needed or requested, 2) Deactivate existing subcommittees which have fulfilled their objectives or have become inactive, 3) Review and approve for board action any resolution, report or publication which undertakes to establish in the name of the association or any of its sections or divisions professional or technical standards, and 4) Promote and fulfill general objectives of the Association as mentioned earlier.

The technical activities of TPC are conducted principally within its subcommittees, which are the heart of the committee. Generally, most subcommittee activities are concerned with the gathering, compiling, and reporting of definitive data and information on corrosion environments, preventive measures and techniques and costs of uncontrolled and controlled corrosion. Additional activities are to: 1) Hold meetings, sponsor symposia and present papers on technical subjects at national, regional and sectional meetings; 2) Promote, guide and carry out special field tests and studies; 3) Promote and guide research studies under the sponsorship of the association; and

* Chairman, National Association of Corrosion Engineers Technical Practices Committee.

4) Promote and fulfill the general objectives of the association as mentioned earlier. An example of item 3 above is the Yale University Research Project under Prof. Robertson on the fundamental metallurgical factors involved in sulfide corrosion cracking. It is anticipated that this type of activity will be expanded in the future as the board of directors recently approved a policy for the promotion of funds for this purpose.

An item of TPC activity which merits further comment to the above, because of its importance and the work involved, is publications. TPC through its subcommittees either wholly prepares or contributes to the preparation of the following: 1) Formal, complete and separately bound committee reports, 2) Special reports and digests carried in Corrosion, 3) Minutes of meetings, 4) Page in Corrosion (this article is an example of this type), and 5) Directory of Technical Practices Committee as carried monthly in Corrosion and as published annually in complete form. In this activity, the valuable assistance and guidance of the Publication Committee and the Central office are gratefully acknowledged. Gratis distribution of the above publications varies and dependent upon type, is made to corporate members, board of directors, TPC chairman, TPC subcommittee members, and in the case of meeting minutes to subcommittee meeting guests. These publications, of course, advertise the achievements of TPC and thus help to promote expansion of its activities. Their distribution also serves as perhaps a minor but nonetheless tangible reward to those members participating in TPC and association activities.

The past achievements of TPC were made possible by the active participation of its many association members and this is gratefully acknowledged by the officers of TPC and the association. To envision where future profitable TPC activities may be conducted, it is of interest to associate past achievements with the fields of industry they represent. A review of association corporate membership indicates that the petroleum, public utilities (power, gas and communications), railroads and chemical industries are moderately to strongly represented. This strength of representation is quite accurately reflected in the activities pursued by TPC since most subcommittee efforts pertain to problems of these groups. It, accordingly, appears that if other corporate and general membership groups were more united in their technical studies or increased their members they might also profitably avail themselves of the benefits to be derived from cooperative technical efforts in the TPC. To further improve and expand its activities TPC invites constructive criticism and comment of its present organization as well as worthwhile subjects for future committee study.

Corrosion Resisting Characteristics Of Iron Modified 90:10 Cupro Nickel Alloy ★

By W. C. STEWART and F. L. LaQUE

Statements and opinions advanced in this paper are to be understood as individual expressions of their authors and not as reflecting the views of the Navy Department or the Naval service at large.

WILLIAM C. STEWART—Started with Denver Rock Drill Mfg. Co. in 1917. On graduation from University of Denver he worked four years on fatigue research under D. J. McAdam, Jr. at the U. S. Naval Engineering Experiment Station, Annapolis, Md. In 1930 he took charge of the Metallurgical Laboratory. His main interests are high-temperature metallurgy, fatigue and sea water corrosion of propulsion machinery on Naval ships.

F. L. LaQUE—In charge of the Corrosion Engineering Section, Development and Research Division, The International Nickel Co., Inc., New York. For the past 20 years his principal interest has been corrosion. He is a chemical and metallurgical engineering graduate of Queen's University, Kingston, Ont., a past president of NACE, and active in the association and in other engineering associations as an officer, committee member and frequent contributor of published information on corrosion.

Abstract

This paper provides a summary of information on the corrosion resisting characteristics of the iron modified 90/10 cupro nickel alloy which is currently being substituted for cupro nickel alloys of higher nickel content, particularly where resistance to attack by salt water is required. Following a brief review of the history of the alloy, information is included on the influence of iron content and heat treatment. Behavior of the alloy under several conditions of exposure to attack by sea water will be described. These conditions will include quiet immersion, exposure at moderate velocity and at high velocity. With regard to the latter, data are presented as secured by jet impingement tests, erosion tests of various sorts, tests in model condensers and in piping systems. The article includes information on fouling characteristics and galvanic behavior.

In addition to data referring to clean sea water, some experiences in sulfide polluted water are described. Appended also is available information on behavior of the alloy in corrosive media other than salt water. Appropriate attention is given welded and brazed joints, and some information is included on physical and mechanical properties and heat transfer characteristics of the alloy.

I Historical

IN THE COURSE of the development of the 70:30 cupro nickel alloy as a material to resist corrosion and erosion by salt water it was discovered that the presence of an appropriate amount of iron in the alloy had a strongly beneficial effect on its performance. The pertinent data were summarized first in a special publication of the British Non Ferrous Metals Research Association issued confidentially to the members of the association in 1939.[1] These British data were brought up to date in a recent paper by G. L. Bailey.[2]

One of the present authors contributed some supporting data on the effects of iron content with particular reference to behavior in natural sea water moving at low velocity[3] and under a variety of exposure conditions in a more recent paper.[4] Some additional pertinent data were included by the present authors in a contribution to an international symposium in 1948.[5]

Interest in the conservation of nickel as a critical material in wartime and in the development of alloys less expensive than the 30 percent cupro nickel as a condenser tube and salt water piping material stimulated research to discover whether the beneficial effect of iron exhibited at the 30 percent nickel level might be utilized to produce a satisfactory copper alloy with a much lower nickel content.

Studies in this direction proceeded in a number of places more or less in parallel and largely independently. Typical of these efforts were those of Tracy and Hungerford[6] and those of the British Non Ferrous Metals Research Association investigators as described by Bailey.[2]

Metallurgical considerations indicated that the 10 percent nickel level would be most appropriate for an alloy of the type being sought. Therefore, most attention was directed to alloys of about this nickel content.

The present authors surveyed the possibilities of other addition elements as well as iron. Those studied were aluminum, zinc, manganese, molybdenum, chromium, silicon, tin and niobium (columbium) in various concentrations and combinations. Of these, only aluminum and iron appeared to be attractive from both the metallurgical and performance points of view. Since an appropriate iron addition achieved as much benefit as the use of aluminum and introduced fewer processing difficulties further attention was focused on the iron modified alloys.*

★ A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

* In the course of these several studies related to resistance to corrosion by salt water there came into existence a U. S. Patent No. 2,074,604 dated March 23, 1937 issued to J. W. Bolton and O. F. Harder. This patent covered some of the compositions of interest. The properties with which this patent was concerned particularly were related to the use of the alloys at elevated temperatures. In addition there are two British Patents, No. 577,065 dated 1939 and 578,283 dated 1943 taken out by the British Non Ferrous Metals Research Association that deal with these alloys.

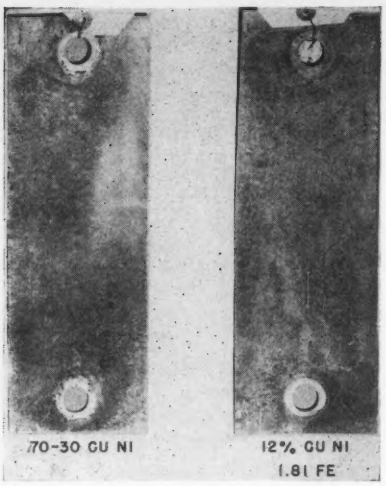


Figure 1—Specimens exposed to flowing sea water at Kure Beach, N. C., for 998 days.

II Influence of Iron Content and Heat Treatment

The solubility of iron in cupro nickel alloys is limited. In his paper[2] G. L. Bailey reviewed the existing information on this subject and referred to studies by Koster and Dannohl,[7] Bradley and Bragg,[8] Bradley, Cox and Goldschmidt,[9] Daniel and Lipson[10,11] and by Hargreaves.[12,13]

By and large the work of these investigators indicated a higher level of iron solubility in the 10 percent cupro nickel alloys than was found by Bailey and his associates. Apparently, iron precipitated from solution is in the form of an iron rich phase which is distributed uniformly in initially homogenous material or preferentially in originally iron rich regions if such exist. This precipitation occurs readily when the alloys are held at 600 degrees C (1112 degrees F) after they have been quenched from 900 degrees C (1652 degrees F). The nature of the changes associated with the precipitation of iron and the very small particle size of the precipitate make detection difficult by ordinary X-ray or metallographic techniques. This will account for the failure of earlier investigators to establish the actual limit of iron solubility. The electron microscope, magnetic measurements and the color of the corrosion product films are more sensitive means of detecting precipitated iron.

The formation of the dispersed iron rich phase is accompanied by a slight increase in hardness and strength through a precipitation hardening mechanism. There is also an increase in magnetic permeability. Both effects are influenced by the iron content of the alloy and by the temperature at which the iron rich phase is precipitated.

Details concerning these effects of iron content and heat treatment were provided in a recent paper by Palmer and Wilson.[14] Their studies showed that the solid solubility of iron in a 10 percent nickel alloy increased from less than 0.10 percent at 400 degrees C (752 degrees F) to 4.8 percent at 950 degrees C (1742 degrees F).

The condition of the iron—whether completely in solution or present partly as an iron rich phase—has a moderate effect on corrosion when the iron content is around 1.5 percent or more as will be illustrated by data to be presented. The nature of this effect of precipitated iron is not so much a serious loss of corrosion or erosion resistance as it is an interference with further benefits that are realized in alloys that contain over about 1.5 percent iron when they are quenched so as to hold the iron in solution. In particular, the thermal effects of welding or brazing operations which might be expected to induce some precipitation of iron are not noticeably detrimental to the corrosion resistance of welded or brazed joints.

Both the British investigations[2] and the authors' have shown that with the iron contents likely to be used—i.e. up to 2 percent—the alloys will demonstrate satisfactory resistance to corrosion and erosion in the conditions in which they will be delivered after ordinary mill processing and annealing. No quench anneal will be required as a final heat treatment and there will be no detrimental effects from welding, brazing or hot forming.

III Behavior in Clean Sea Water

1. Quiet Immersion

As indicated previously, iron modified alloys were included in some of the preliminary surveys.

One group of specimens was immersed in the sea water channel at Kure Beach, North Carolina, for 998 days under conditions where fouling could occur and where the low rate of flow would favor pitting of susceptible materials. Included was an alloy which contained 12 percent nickel and 1.8 percent iron in the form of as-rolled, cold rolled strip. The results of this exposure showed a very low rate of corrosion equivalent to penetration at a rate of only 0.0002 ipy. as calculated from weight loss and maximum depth of pitting of only 0.008-inch in the 998 days. This was only one-third the weight loss and depth of pitting of a low iron content 70:30 cupro nickel alloy exposed for the same time in the same test. The appearances of the 88:12 and 70:30 cupro nickel specimens after this exposure are shown in Figure 1.

Subsequent tests under the same conditions for a year showed similarly good performance of a 10 percent nickel alloy which contained 0.8 percent iron and indicated that the iron content need not be as high as 1.8 percent to achieve good resistance to corrosion by sea water under these conditions of exposure. In this shorter test, the rate of corrosion was 0.0006 ipy and there was no measurable pitting. This rate of attack was only one-sixth that of arsenic inhibited Admiralty brass exposed for the same time in the same test.

More recently, through the courtesy of the Revere Copper and Brass Company, a series of 10 percent cupro nickel alloys was provided. These covered a wide range of iron contents with different heat treatments at the higher levels of iron content. The heat treatments were a 1300 degrees F (705 degrees C) anneal applied to precipitate iron and a quench after holding at 1700 degrees F (930 degrees C) for eight

hours to retain as much iron as possible in solid solution.

These specimens were subjected to exposure to sea water under a variety of conditions to be described. Among these was simple immersion in the ocean inlet at Wrightsville Beach, North Carolina, for 300 days. Here again, the exposure conditions were favorable to marine fouling. In addition, there was a fairly strong tidal current which reached a maximum of about four feet per second at flood tide. The results of this exposure are shown graphically in Figure 2. It will be observed that under these conditions of exposure all alloys showed good resistance to corrosion with a trend towards minimum corrosion within the range of iron content between 0.8 percent and 2.2 percent. The effect of heat treatment was not strong and only with the 3.5 percent iron alloy did the quench to retain iron in solution exert a slight beneficial effect with respect to weight loss.

There was sufficient velocity of flow to produce some edge erosion of vulnerable compositions. While this could not be measured quantitatively, some qualitative ratings could be made by visual examination. These showed best and substantially equal performance for the 0.82 percent iron alloy, the 1.51 percent iron alloy in both conditions of heat treatment and the alloys of higher iron content in the quenched condition only.

As had been noticed regularly by other investigators[2] the color of the corrosion product films that developed on the alloys that contained 1.5 percent or more iron was influenced greatly by the heat treatment. When the alloys were quenched to hold all the iron in solid solution the corrosion product films had the usual golden brown color characteristic of cupro nickels in sea water. However, when the high iron alloys were annealed at 1300 degrees F to permit precipitation of a high iron content phase, the corrosion products included an outer black magnetic and non-adherent film.

Another very important observation from these tests was that all alloys remained substantially free from marine fouling irrespective of their iron content or heat treatments. On a fouling rating scale where 10 represents complete freedom from fouling these alloys were rated from 8.5 to 10. Their appearance after this exposure is shown in Figure 3. The extent of fouling that could have occurred on the 90:10 alloys is indicated by the growth on the racks and fastenings which were made of Monel which was not anti-fouling.

This freedom from fouling of the iron modified 90:10 cupro nickels under these conditions of exposure was in line with their rates of corrosion which permitted a release of copper in corrosion products at an average rate above the 5 mg. per sq. dm. per day value previously established as being required for a copper alloy to keep itself free from adherent fouling organisms in sea water.[15]

Having in mind that some of these alloys also are highly resistant to erosion by sea water, it is important to note that the iron modified 90:10 alloy provides in one composition freedom from fouling in low velocity water with excellent resistance to

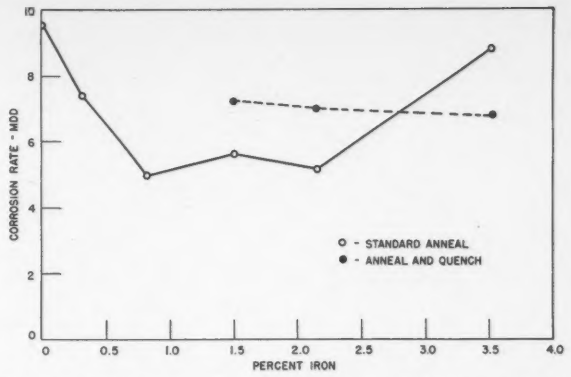


Figure 2—Effect of iron content on corrosion rate of 90-10 cupro nickel in sea water at Wrightsville Beach, N. C. 300 days, Jan.-Nov., 1949. Velocity of water 0 to 4 fps.

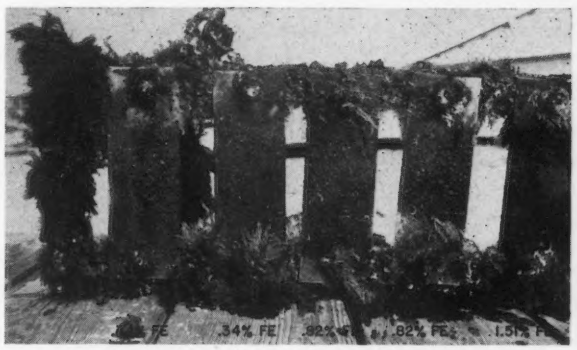


Figure 3—90-10 copper nickel in sea water at Wrightsville Beach 300 days.

attack by water at high velocity. This is especially valuable for services where both qualities are required—as for example—in salt water piping systems and as a hull sheathing.

Previous experience with other corrosion resisting copper alloys in sea water had shown that when the composition was such as to provide the required level of resistance to erosion by sea water at high velocity the rate of corrosion and release of copper in water moving at low velocity was too low to prevent fouling. On the other hand, when sufficient corrosion would occur in low velocity water the resistance to erosion in water at high velocity was not good. Until the advent of the iron modified 90:10 cupro nickel alloys the prospect of combining both qualities in a single material did not appear to be bright.

2. Immersion in Sea Water at Moderate Velocity

In order to observe the performance of these alloys in sea water moving constantly at a moderate velocity, specimens of the series which covered a range of iron contents and heat treatments were immersed in a wooden trough through which there was a continuous flow of clean sea water at a velocity of about two feet per second. The duration of this test was 369 days from January 1949 to January 1950. The results are shown graphically in Figure 4. The appearances of specimens after exposure are shown in Figure 5. As was the case in the tests in the inlet at Wrightsville Beach, maximum resistance to corrosion

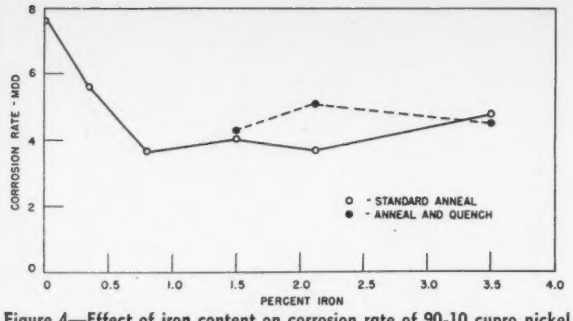


Figure 4—Effect of iron content on corrosion rate of 90-10 cupro nickel in sea water in the trough at Kure Beach, N. C. 369 days, Jan., 1949-Jan., 1950. Velocity of water 2 fps.

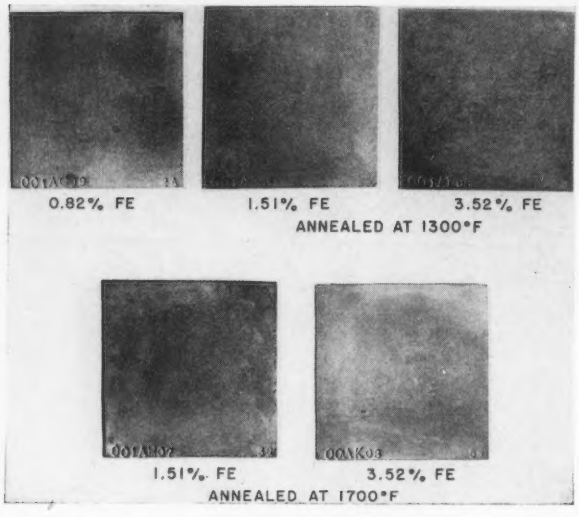


Figure 5—Appearance of 90-10 cupro nickel specimens exposed in trough for one year.

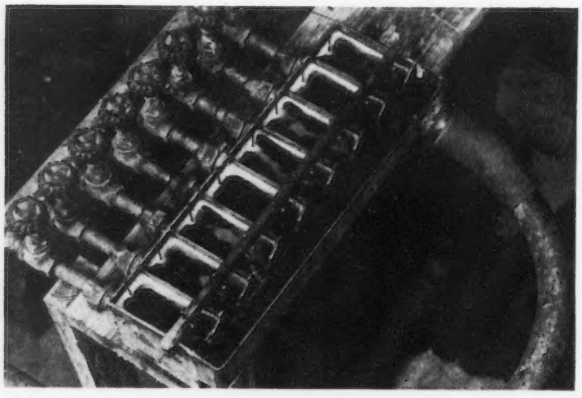


Figure 6—Aspirator type sea water jet test apparatus.

was exhibited by the alloys that contained 0.8 percent or more iron. The effects of heat treatment were small and there was no evidence of any requirement of a quench anneal, even at the highest iron level, under these conditions of exposure.

By way of comparison, specimens of 70:30 cupro nickel which contained 0.05 percent iron were corroded three times as fast (12 mdd) as the 90:10 alloys with 0.8 percent or more iron while a 70:30

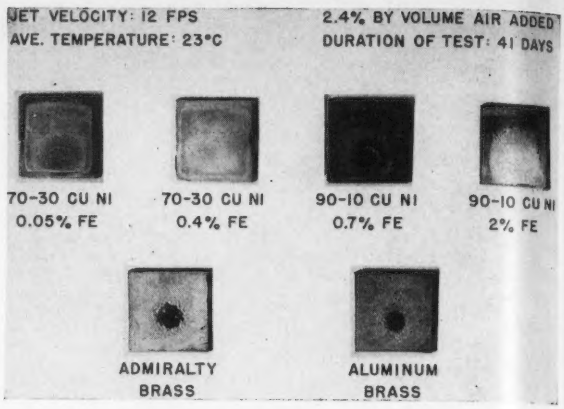


Figure 7—Appearance of specimens exposed in aspirator type sea water jet apparatus.

cupro nickel which contained 0.5 percent iron was corroded at half the rate—2 mdd. None of the alloys suffered any significant pitting under these conditions of exposure.

3. Tests at High Velocity

Because of the special interest in the use of these alloys to resist corrosion, erosion and impingement attack by sea water moving at high velocity, specimens were subjected to several kinds of test covering such conditions.

a. Jet Impingement Tests. Two types of jet impingement test apparatus were used. The first was the aspirator type shown in Figure 6. This apparatus was described in detail in earlier papers by the present authors.[4,5] In action, the apparatus causes a stream of sea water moving at high velocity to impinge on the surface of a test specimen held in front of the submerged jet. The shape of the jet is such that air may be sucked into the jet stream through a tube which projects above the water. Typical results of many tests made with this apparatus are given in Table I. The appearances of specimens after this test are shown in Figure 7.

The second type of jet impingement test was carried out with apparatus developed by the British Non Ferrous Metals Research Association and secured from them for operation at Harbor Island, North Carolina Testing Station. This apparatus and its use were described in detail in a recent paper by May and Stacpoole.[16]

A principal difference between this apparatus and the aspirator type previously described is that in the British apparatus the air brought to the device under pressure is mixed with the water in a specially designed manifold from which a uniform mixture of water and entrained air bubbles is fed to the several submerged jets joined to this manifold. The major difference in the use of this British apparatus at Harbor Island as compared with its use in England is that at Harbor Island there is a continuous supply of already air saturated sea water which passes through the apparatus only once. The laboratory in England is remote from the sea so that it is necessary to use water trans-

ported to the laboratory. Since the supply of this water is limited, it is necessary to re-circulate it over and over again during the test period. Comparative tests have indicated that the same nominal testing conditions at Harbor Island are much more severe towards many alloys than they are when used with the re-circulated water in England. This must be taken into account when comparing the results shown in Tables I and II with those reported for the same alloys under otherwise similar testing conditions in the British literature.[2,16] The apparatus as it is set up at Harbor Island is shown in Figure 8. Typical results with this apparatus on specimens of the same materials as were tested in the aspirator type apparatus as covered by Table I are shown in Table II. The appearances of the specimens after exposure are shown in Figure 9.

It will be observed from the data in Tables I and II and from the photographs of the test specimens after exposure, that the 90:10 cupro nickel alloy which contained either 0.7 or 2 percent iron demonstrated good resistance to impingement attack in these tests. The 90:10 alloy was much better than both Admiralty brass and the 70:30 cupro nickel of low iron content, was equal to or better than aluminum brass and was about equal to the 70:30 cupro nickel with high iron content.

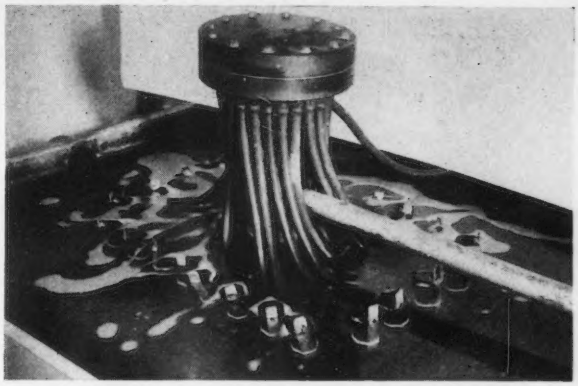


Figure 8—British jet test apparatus as set up at Harbor Island, North Carolina.

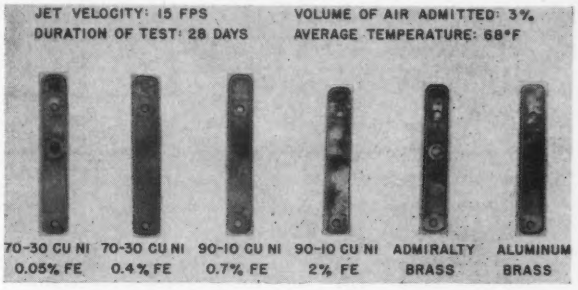

JET VELOCITY: 15 FPS
DURATION OF TEST: 28 DAYS
VOLUME OF AIR ADMITTED: 3%
AVERAGE TEMPERATURE: 68°F
70-30 CU NI 0.05% FE
70-30 CU NI 0.4% FE
90-10 CU NI 0.7% FE
90-10 CU NI 2% FE
ADMIRALTY BRASS
ALUMINUM BRASS

Figure 9—Appearance of specimens after exposure in British Non-Ferrous Metals Research Association jet test apparatus.

Similar tests with the series of 90:10 cupro nickel alloys of different iron contents and heat treatments disclosed the following features:

1. As the iron content increased the area of the pattern of impingement attack under the jet decreased while the depth of attack also decreased but not to as great an extent.
2. With the alloys that contained 1.5 percent iron the resistance to impingement attack in a jet test was not influenced by heat treatment to hold iron in solution or to permit it to precipitate as a high iron content phase.
3. A quench anneal to hold iron in solution improved the resistance to impingement attack of the 2 percent iron alloy even though, without the quench anneal, this alloy was as good as those of lower iron content—0.8 percent and 1.5 percent iron.
4. At the 3.5 percent iron level a quench anneal appeared to be necessary to retain good resistance to impingement attack. Actually, in the quenched condition the 3.5 percent iron alloy was much superior to those of lower iron content. This effect is illustrated by the specimens shown in Figure 10 after jet tests in the British Apparatus at 15

TABLE I
Typical Results of Impingement Tests
Made With Aspirator Type Jet Test Apparatus
Peak Jet Velocity: 12 feet per second. Duration of Test: 41 days.
Volume of air admitted: 2.4%. Average Temperature: 73° F.

MATERIAL	COMPOSITION—PER CENT							Average Weight Loss in Mg. per Day	Max. Depth of Impingement Attack in Ins. per Month
	Cu	Ni	Fe	Mn	Al	Zn	Sn		
1. 90:10 Cu Ni 0.7 percent Fe...	89.06	9.8[1]	0.71	0.19	....	0.20	....	4.5	0.003
2. 90:10 Cu Ni 2 percent Fe...	87.18[1]	10.25	2.07	0.46	....	0.04	....	7.5	0.001
3. Admiralty Brass	71.11	....	....	....	....	27.87[1]	0.98	11.3	0.011
4. Aluminum Brass	76.55	....	....	....	2.18	21.25[1]	....	5.3	0.007
5. 70:30 Cu Ni Low Fe.....	69.05	30.26[1]	0.06	0.48	....	0.15	....	9.6	0.006
6. 70:30 Cu Ni High Fe.....	68.92	30.16[1]	0.47	0.45	....	....	....	2.7	0.002

[1] By Difference.

TABLE II
Typical Results of Impingement Tests
Made With British Non-Ferrous Metals Research Association
JET TEST APPARATUS
Jet Velocity: 15 feet per second. Volume of air admitted: 3%. Average Temperature: 68° F.
Duration of test: 28 days.

MATERIAL	COMPOSITION—PER CENT							Average Weight Loss in Mg. per Day	Max. Depth of Impingement Attack in Ins. per Month
	Cu	Ni	Fe	Mn	Al	Zn	Sn		
90:10 Cu Ni 0.7 percent Fe.....	89.06	9.8[1]	0.71	0.19	....	0.20	....	9	0.001
90:10 Cu Ni 2 percent Fe.....	87.18[1]	10.25	2.07	0.46	....	0.04	....	7	0.002
Admiralty Brass..	71.11	....	....	....	....	27.87[1]	0.98	30	0.025
Aluminum Brass..	76.55	....	....	....	2.18	21.25[1]	....	7	0.004
70:30 Cu Ni Low Fe	69.05	30.26[1]	0.06	0.48	....	0.15	....	20	0.004
70:30 Cu Ni High Fe.....	68.92	30.16[1]	0.47	0.45	....	....	....	6	0.003

[1] By difference.

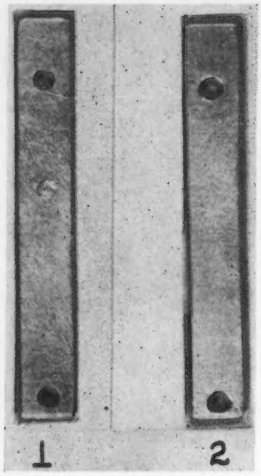


Figure 10—Appearance of 90-10 cupro nickel specimens after exposure in British Non-Ferrous Metals Research Association jet test apparatus. Jet velocity 15 fps. Duration of test 28 days. Volume of air admitted 2-4 percent. Average temperature 64 degrees F. Specimens 1—3.52 percent Fe, annealed at 1300 degrees F. Specimen 2—3.52 percent Fe, annealed at 1700 degrees F.

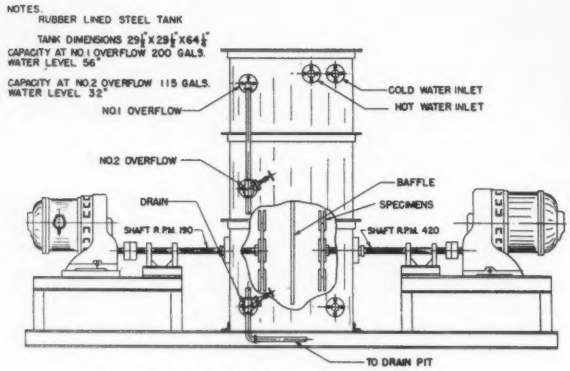


Figure 11—Rotating disc corrosion apparatus.

fps for 28 days at 64 degrees F with 3 percent by volume air bubbles present.

b. Tests with Rotating Disc Corrosion Apparatus. Apparatus of the type shown in Figures 11 and 12 was described in some detail in an earlier paper.[5] It has been found to yield consistent and reproducible results and has been particularly useful for comparing materials as to their abilities to resist the erosive effects of sea water at high velocity.

This type of test was used, therefore, to examine the effects of iron content and heat treatment in a series of iron modified 90:10 cupro nickel alloys provided through the courtesy of the American Brass Company. The particular testing machine used for this study at the Harbor Island Test Station was one fitted with two discs that could be rotated independently by separate motors at two speeds so as to permit observations of effects of two ranges of velocity in the same water at the same temperature at the same time. These tests were run with the water overflowing through the No. 1 overflow in Figure 11. This reduced the amount of air whipped into the water by the rotation of the discs. Contrary to popular belief with respect to many materials it has been found that with the iron modified cupro nickels the presence of large amounts of air bubbles in the water reduces rather than increases erosion in this testing device. Thus air bubbles were excluded so as to permit attack to occur at maximum rates. The average water temperature during the 55 day test was 73 degrees F. The specimens measured ¾-inch x 4-inch x 1/16-inch.

TABLE III

Magnetic Permeabilities and Corrosion-Erosion Rates of Copper-Nickel Alloys Tested in Flowing Sea Water

MATERIAL	MAGNETIC PERMEABILITY			CORROSION-EROSION RATE, MDD					
				Velocity—30 FPS			Velocity—15 FPS		
	Cond. A	Cond. B	Cond. C	Cond. A	Cond. B	Cond. C	Cond. A	Cond. B	Cond. C
90-10 Cu Ni, 0.01 percent Fe..	1.00	1.00	1.00	138	138	137	106	105	104
90-10 Cu Ni, 0.48 percent Fe..	1.00	1.00	1.00	119	115	124	71	72	85
90-10 Cu Ni, 0.71 percent Fe..	1.00	1.00	1.18	121	118	110	64	75	49
90-10 Cu Ni, 0.95 percent Fe..	1.00	1.04	1.14	96	93	104	27	63	47
90-10 Cu Ni, 1.19 percent Fe..	1.00	1.27	1.55	87	98	87	26	65	39
90-10 Cu Ni, 1.44 percent Fe..	1.00	1.28	1.83	36	84	99	17	58	49
90-10 Cu Ni, 1.96 percent Fe..	1.00	1.44	2.40	26	79	84	10	55	51
70-30 Cu Ni, 0.05 percent Fe[1]..	.....	.....	.....	250	.....	.....	192	.....	.....
70-30 Cu Ni, 0.46 percent Fe[1]..	.....	.....	.....	75	.....	.....	35	.....	.....

[1] Recrystallized condition.

Cond. A—Quenched from 900° C; iron in solution.

Cond. B—Quenched from 900° C; reheated 2 hours at 550° C, except for alloys containing 1.00% or more iron, which were reheated 2 hours at 600° C; partial precipitation of iron-rich phase.

Cond. C—Quenched from 900° C, reheated 8 hours at 650° C; maximum precipitation.

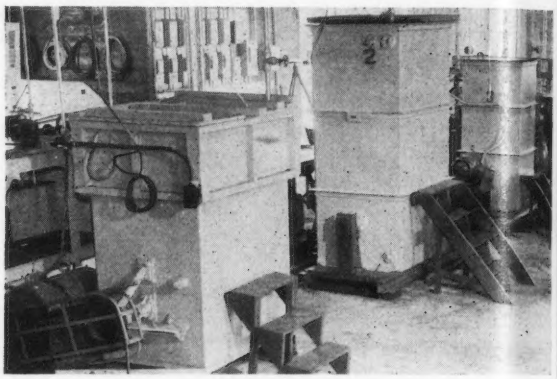


Figure 12—E.E.S. apparatus as set up at Harbor Island, N. C.

The chemical compositions, magnetic permeabilities (as measured with a field strength of 200 oersteds) and the corrosion rates observed are shown in Table III. Included also were specimens of high and low iron content 70:30 cupro nickel for direct comparison with the 90:10 alloys.

Appearance of a group of specimens mounted on a disc after test is shown in Figure 13.

Results are also shown graphically in Figures 14, 15 and 16 and the appearances of the several specimens after exposure in Figures 17 to 22, inclusive.

The results of these tests with respect to the effects of iron content were quite consistent with those of

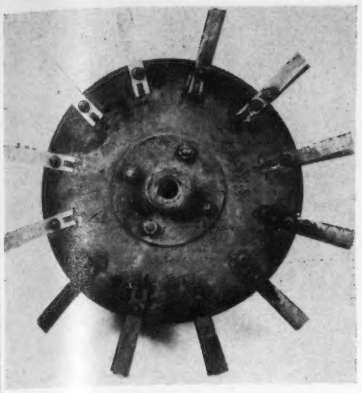


Figure 13—Disc containing 24 corrosion specimens after 60 days' test.

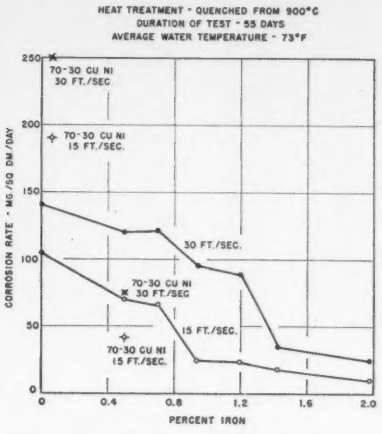

HEAT TREATMENT - QUENCHED FROM 900°C
DURATION OF TEST - 55 DAYS
AVERAGE WATER TEMPERATURE - 73°F
70-30 CU NI 30 FT./SEC.
70-30 CU NI 15 FT./SEC.
30 FT./SEC.
70-30 CU NI 30 FT./SEC
15 FT./SEC.
70-30 CU NI 15 FT./SEC.
CORROSION RATE - MG./SQ. DM./DAY
PERCENT IRON

Figure 14—90-10 copper nickel alloys rotated in sea water at 15 and 30 ft/sec.

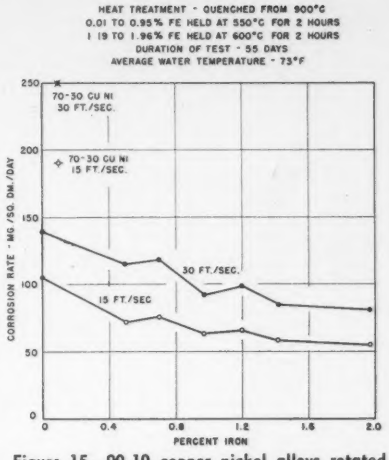

HEAT TREATMENT - QUENCHED FROM 900°C
0.01 TO 0.95% FE HELD AT 550°C FOR 2 HOURS
1.19 TO 1.96% FE HELD AT 600°C FOR 2 HOURS
DURATION OF TEST - 55 DAYS
AVERAGE WATER TEMPERATURE - 73°F
70-30 CU NI 30 FT./SEC.
70-30 CU NI 15 FT./SEC.
30 FT./SEC.
15 FT./SEC
CORROSION RATE - MG./SQ. DM./DAY
PERCENT IRON

Figure 15—90-10 copper nickel alloys rotated in sea water at 15 and 30 ft/sec.

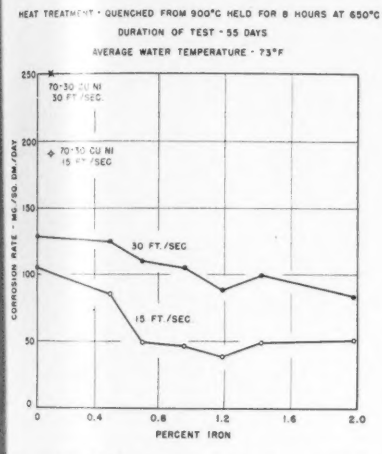

HEAT TREATMENT - QUENCHED FROM 900°C HELD FOR 8 HOURS AT 650°C
DURATION OF TEST - 55 DAYS
AVERAGE WATER TEMPERATURE - 73°F
70-30 CU NI 30 FT./SEC.
70-30 CU NI 15 FT./SEC
30 FT./SEC
15 FT./SEC
CORROSION RATE - MG./SQ. DM./DAY
PERCENT IRON

Figure 16—90-10 copper nickel alloys rotated in sea water at 15 and 30 ft/sec.

the other tests previously described and with those of Bailey[2] and his associates. Considering first the alloys quenched so as to hold the iron in solution (Figure 14) it will be observed that there was a continuous improvement in erosion resistance as the iron content was increased. In the tests at 15 feet per second velocity the effect of iron tended to level off around 1 percent whereas under the more severe erosive conditions at 30 feet per second the levelling off occurred around 1.4 percent.

When part of the iron was precipitated by holding at temperatures from 550 degrees to 650 degrees C (Figures 15 and 16) the beneficial effect of iron in percentages over about 1 percent was much less. Nevertheless even after heat treatment C, which precipitated the maximum amount of iron, the 90:10 cupro nickel alloys were definitely superior to the low iron 70:30 cupro nickel alloy which has been used extensively in marine service and were about equal to the high iron 70:30 cupro nickel which is recognized as a most reliable material where a high order of resistance to corrosion and erosion by sea water is required. This comparison is facilitated by reference to the data assembled in Table III.

It is evident, therefore, that although some further improvement of the higher iron content alloys might be achieved by a quench annealing heat treatment, a satisfactory performance may be expected from these alloys even when a maximum amount of iron may be present as a dispersed precipitate. This means that no quench anneals will be required in mill processing and that no serious effects of the heat of welding or hot forming need be anticipated.

c. **Tests with Rotating Spindle Erosion Testing Apparatus.** Still another type of testing apparatus used to study these alloys was the rotating spindle apparatus shown in Figure 23.

In this test, specimens in the form of discs 5 inches in diameter were mounted on and insulated from vertical spindles which were rotated by a V-belt drive at 1140 rpm. This achieved a velocity which varied with the radius of rotation to a maximum of 24.9 feet per second at the periphery. The specimens were submerged in a tank through which clean sea water flowed continuously. There was no vortex around the spindle and the water remained clear and free from entrained air bubbles.

A typical group of specimens after this test. for 60 days is shown in Figure 24.

It will be observed that with each material there was an apparently critical radius of rotation or velocity below which the alloys were able to form and retain protective corrosion product films and above which no films were held and corrosion or erosion proceeded. The nature of this effect for four of the alloys of interest is shown graphically in Figure 25. The depths of attack plotted were determined by micrometer measures of the corroded specimens. It will be observed that in this

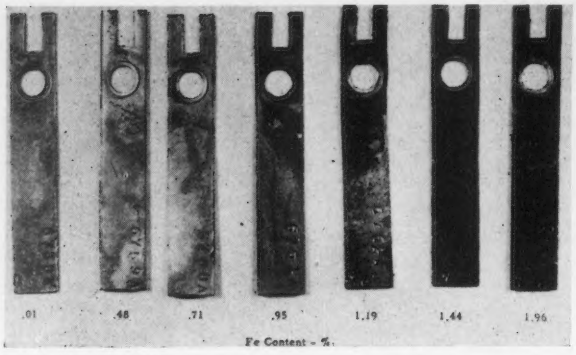


Figure 17—90-10 copper nickel alloys after 55 days in sea water at 30 ft/sec. Heat treatment—annealed at 900 degeres C and quenched.

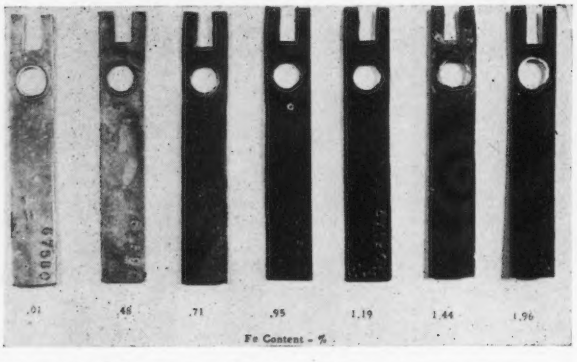


Figure 18—90-10 copper nickel alloys after 55 days in sea water at 30 ft/sec. Heat treatment—annealed at 900 degrees C, quenched. Reheated to 550 degrees for two hours. Alloys of 1.19 to 1.96 percent Fe heated to 600 degrees C for two hours.

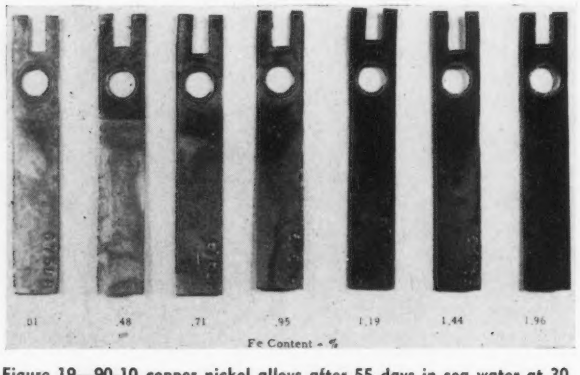


Figure 19—90-10 copper nickel alloys after 55 days in sea water at 30 ft/sec. Heat treatment—annealed at 900 degrees C, quenched. Reheated to 650 degrees C for eight hours.

particular test the 90:10 cupro nickel which contained 0.7 percent iron was actually superior to the 70:30 cupro nickels as well as to Admiralty brass.

The inception of severe attack of the Admiralty brass was especially abrupt and the greatest attack on this alloy occurred near the margin of its protective film rather than at the periphery where the velocity was higher.

All of the cupro nickels were characterized by the extreme uniformity of the corrosion that occurred in this test—as shown in Figure 24 the eroded surfaces were actually smoother than those nearer the centers of the discs. This freedom from pitting

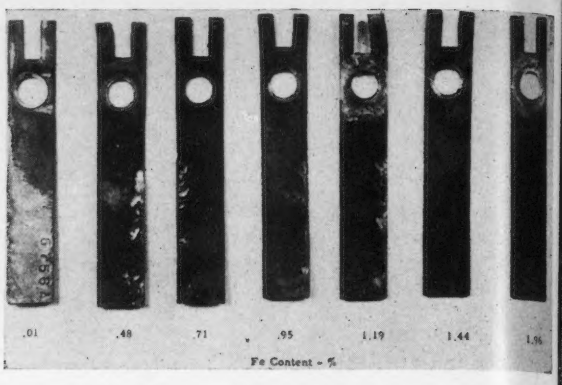


Figure 20—90-10 copper nickel alloys after 55 days in sea water at 15 ft/sec. Heat treatment—annealed at 900 degrees C and quenched.

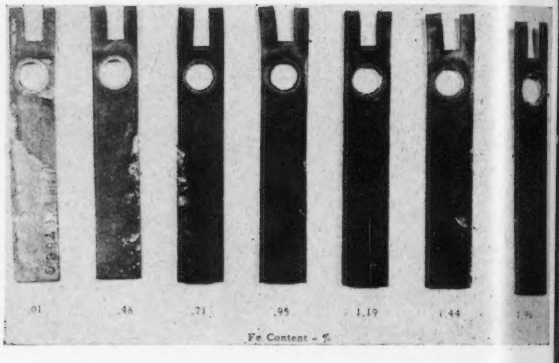


Figure 21—90-10 copper nickel alloys after 55 days in sea water at 15 ft/sec. Heat treatment—annealed at 900 degrees C, quenched. Reheated to 550 degrees C for two hours. Alloys of 1.19 to 1.96 percent Fe heated to 600 degrees C for two hours.

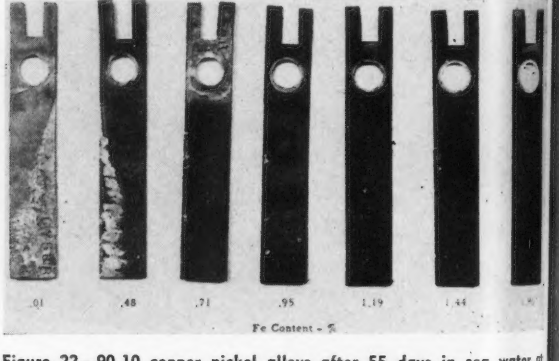


Figure 22—90-10 copper nickel alloys after 55 days in sea water at 15 ft/sec. Heat treatment—annealed at 900 degrees C, quenched. Reheated to 650 degrees C for eight hours.

under such conditions should be a valuable property of the 90:10 cupro nickels as well as the 70:30 alloys. Results of similar tests on a series of cupro nickel alloys are shown in Table IV. The 1.5 percent iron content 90:10 alloy exhibited satisfactory resistance to erosion when heat treated to precipitate iron. With the 3.5 percent iron alloy it was necessary to hold the iron in solution by quenching to secure maximum resistance to erosion.

4. Condenser Tubes

The use of copper-nickel alloy tubes in main and auxiliary condensers has been required by the Navy since 1933. As a result of this experience, the 70-30

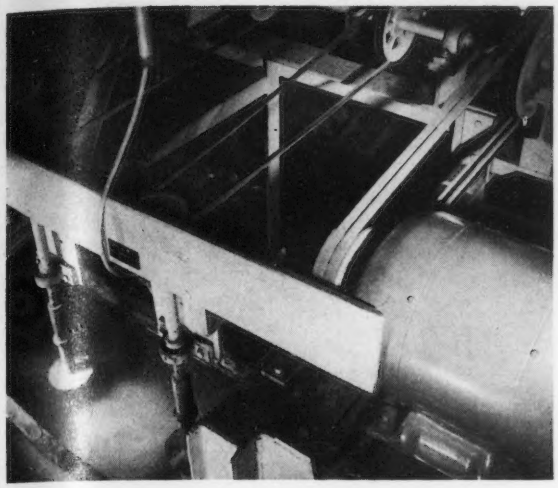
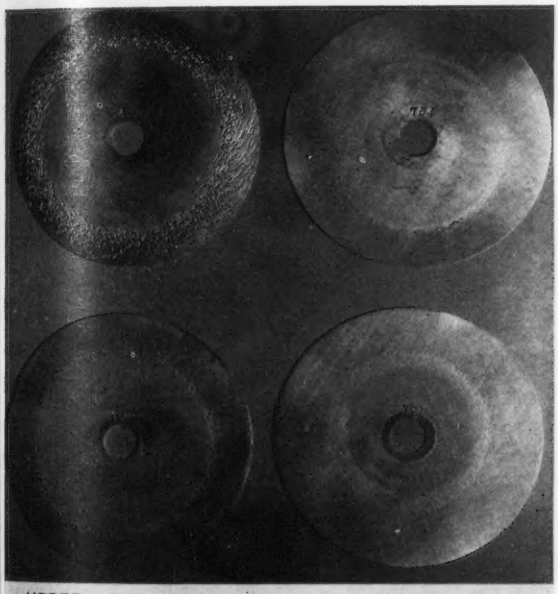


Figure 23—Rotating spindle apparatus at Harbor Island, N. C.



UPPER LEFT: ADMIRALTY BRASS
UPPER RIGHT: 90-10 CUPRO NICKEL, 0.7% FE
LOWER LEFT: 70-30 CUPRO NICKEL, 0.4% FE
LOWER RIGHT: 70-30 CUPRO NICKEL, 0.05% FE

Figure 24

copper-nickel alloy has come to be regarded as the most satisfactory material for condenser tubes for sea water service. This conclusion was reached even before it was recognized that small additions of iron to the alloy greatly enhanced its resistance to corrosion-erosion attack. Currently, Navy Department Specification MIL-T15005 for copper-nickel condenser tubes requires an iron content within the range 0.40-0.70 percent for the 70-30 alloy.

As far back as 1945, laboratory tests carried out in brackish river water of copper-nickel alloys containing 5, 10 and 20 percent nickel, with iron contents ranging from 0.005 to 1.5 percent had indicated more than ordinary merit for the 90-10 copper-nickel alloys

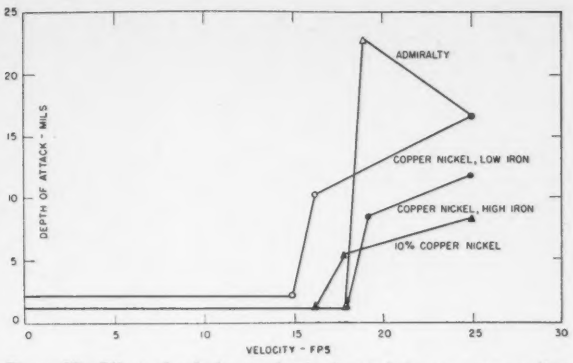


Figure 25—Effect of velocity on depth of attack in sea water at Kure Beach, N. C., for 60 days.

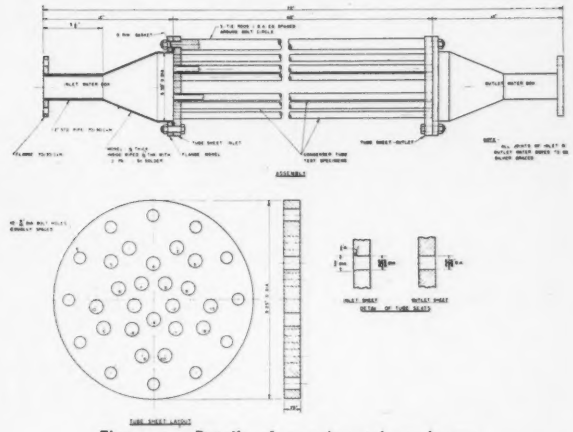


Figure 26—Details of experimental condenser.

containing about 1.0 percent iron. In 1950 a systematic investigation was undertaken at the U. S. Naval Engineering Experiment Station to determine the suitability of the alloys for condenser tubes, tube sheets and other applications. In addition to tests of laboratory specimens, tests were made of experimental condensers and piping systems. More than a dozen experimental condensers of the type shown in Figure 26 have been set up for test. Each test condenser contains twenty ⅝-inch OD tubes 48 inches long. More than 20 materials have been tested or are under test in these units. Among these are several new alloys as well as a number of older materials that are being re-examined in search for a suitable alternate for the 70-30 copper-nickel alloy. The tubes were expanded in ¾-inch thick tube sheets by means of an electronically controlled tube expander. The design of the tube seats and the rolling procedure were in accordance with standard Navy practice. After expanding, the inlet end of the tubes was flared. The holding power for ⅝-inch OD, 18 gauge condenser tubes of 90-10 copper-nickel alloy containing 2 percent iron was determined in comparison with similar tubes of 70-30 copper-nickel alloy. The 90-10 tubes were rolled in newly prepared tube seats in a ¾-inch sheet of 90-10 copper-nickel alloy containing 1.35 percent iron. The 70-30 tubes were rolled in a ¾-inch sheet of like material. The average holding power for six 90-10 tubes was 1860 pounds as compared with 2045 pounds for the 70-30 tubes.

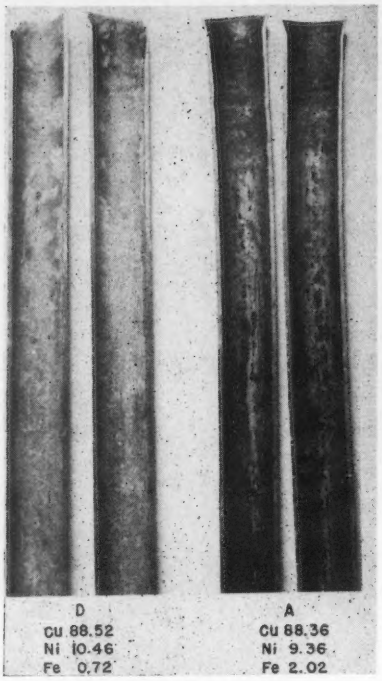


Figure 27—Condenser tubes, 90-10 copper nickel.

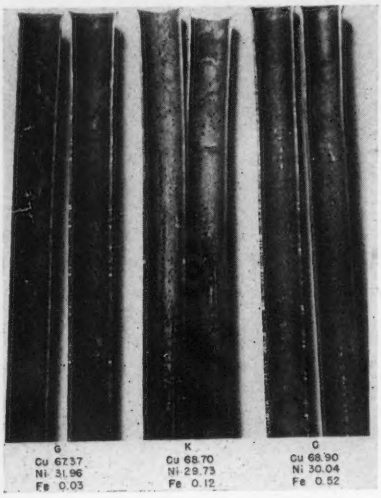


Figure 28—Condenser tubes, 70-30 copper nickel.

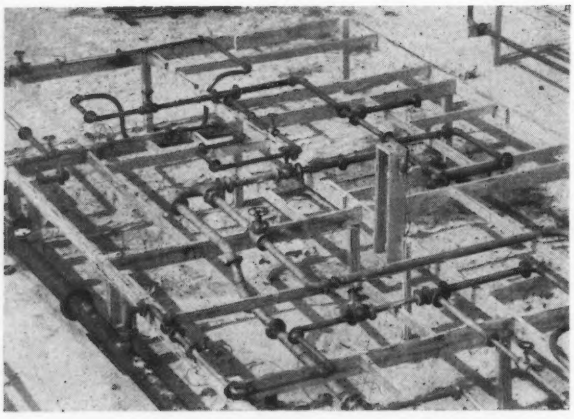


Figure 29—90-10 copper nickel piping systems installed at Wrightsville Beach, N. C., Sept., 1951.

Water boxes were made of 1/16-inch thick Monel metal shaped in the form of a funnel to promote uniform distribution of the water over the tube sheet. The inside surface of the inlet boxes was wiped with 2-1 lead-tin alloy as is general Navy practice.

The first five condensers were set up for test at the Marine Testing Station at Kure Beach, North Carolina. The test was started in November 1949 and was operated continuously except for occasional power failures until March 1950, a total of 4.7 months. The velocity of flow through the tubes was 10 feet per second. The temperature of the sea water ranged from 47 degrees to 61 degrees F. At the end of the 4.7 months period the condensers were inspected and sample tubes removed for laboratory examination.

During the summer of 1950, the facilities for corrosion testing at Kure Beach were moved to the Harbor Island Laboratory at Wrightsville, North Carolina. The test was continued at the new location with five other condensers. Testing of the second group of condensers was started in November, 1950.

The chemical composition and other information for the 90-10 copper-nickel condenser tubes and 70-30 copper-nickel tubes which were included for comparison are given in Table V. Figures 27 and 28 show the inlet end of representative tubes. Tubes, alloys A and C, have shown the maximum resistance to corrosion-erosion attack at the inlet end. Alloy A is a 90-10 composition containing 2 percent iron, and Material C a 70-30 copper-nickel alloy containing 0.52 percent iron. Tube, Alloy D, a 90-10 copper-nickel alloy containing 0.72 percent iron, showed the least resistance to inlet-end attack. Most of the flare at the inlet-end of tube K has been eroded away while tube G sustained considerable thinning at the flare.

The corrosion film on the 90-10 alloy containing high iron, Material A, was black while that of 90-10 alloy containing 0.7 percent iron was golden brown in color. The light brown corrosion film produced in sea water is characteristic of the alloy when the iron is in solution. The black corrosion film indicates the presence of the iron rich phase. Although the tubes of the high iron 90-10 copper-nickel alloy had not been treated in the process of manufacture so as to retain the iron in solution, the resistance to corrosion-erosion was not affected to a significant degree.

Results of test for tubes tested in the experimental condensers indicate the test conditions for producing inlet end attack were rather severe. Of the copper-nickel alloys, Material D, a 90-10 copper-nickel alloy containing 0.7 percent iron sustained severe inlet end damage. Similar behavior was exhibited by tubes of several other types of alloys. Inlet end damage was greater than that reported by Freeman and Tracy[17] for tests carried out in a tubular condenser at Kure Beach, N. C. The velocity of flow in their tests was 11.7 ft/sec and the duration of test ten months.

The fact both series of tests were made in experimental condensers at Kure Beach has led to speculation as to causes for the different results obtained. It has been mentioned that galvanic current between the tubes and solder-coated Monel water boxes of the Navy test units may have been responsible for the increased attack. Potential readings for solder coating on Monel metal water box versus a saturated calomel-half cell showed that the solder, after a short period of exposure to sea water, was nearly as noble as the Monel metal. However, the tests dif-

fered in several other particulars. Of special interest are the equivalent entrance velocities, the value for the station test units being four times that of the condenser employed by Freeman and Tracy. This condition would be expected to result in greater turbulence in the station condensers. Materials of construction, spacing of tubes and method of installing the tubes in the station test units more nearly simulate conditions that prevail in Naval condensers. It is also mentioned that the Everdur tube sheet and brass ferrules used by Freeman and Tracy may have furnished some galvanic protection for the copper-nickel tubes.

5. Piping Systems

Corrosion in salt water pipe lines of Naval vessels has been a source of trouble extending back to the days when galvanized wrought iron pipe was used for this purpose. During the years, there has been much speculation as to the underlying causes of corrosion-erosion encountered in salt water pipes. With the construction of lighter and more powerful ships of the modern Navy, the use of heavy-wall pipe to provide for corrosion loss was no longer tenable. This led to the development of a line of sweated composition bronze fittings for use with thin-wall copper-nickel alloy tubing. Severe service conditions imposed on salt water piping systems, particularly during the years of the war, indicated that further improvement was necessary in order to insure reasonable freedom from corrosion-erosion failure.

Examination of pipes taken from service revealed that a large proportion of failures occurred in the smaller pipes 3-inch IPS, and smaller. In nearly every instance failure was characterized by corrosion-erosion damage in the pipe downstream of valves, fittings and bends. Corrosion-erosion damage was most severe in pipes immediately downstream of globe valves. Inasmuch as practically all failures were experienced in pipes of 70-30 copper-nickel alloy containing low iron, it appeared in the light of laboratory experiments, that with the adoption of 70-30 copper-nickel alloy containing about 0.50 percent iron the number of failures due to corrosion-erosion would be reduced very materially. Previously, tests had indicated that no major improvement could be expected from design changes short of reducing the number of valves, fittings and branch connections. Some slight improvement was noted with long-turn elbows and saddle fittings in lieu of direct branch connections. It was also found that angle valves produced less turbulence than standard globe valves. Plastic inserts installed in pipes downstream of valves and fittings proved effective against corrosion-erosion attack in these vulnerable areas. A similar line of investigation was followed when it became apparent that efforts should be made to conserve nickel by substituting 90-10 copper-nickel for the 70-30 alloy in ships' salt water piping systems.

Pipes of 90-10 copper-nickel alloy were substituted for several branches in a test piping system consisting of 70-30 copper-nickel and several other alloys that had been under test in sea water since 1948. One branch consisting of six sections of 1¼-inch 90-10 pipe was installed in November 1950. Three sections were of 90-10 copper-nickel containing 0.87 percent iron while the material of the other three

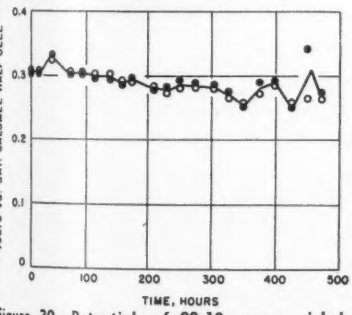


Figure 30—Potentials of 90-10 copper nickel in sea water flow 13 fps, average temperature 26 degrees C.

TABLE IV

Results of Corrosion-Erosion Tests On Rotating Spindle Machine for 60 Days

Sea Water Temperature 80° F

MATERIAL	COMPOSITION Cu	Ni	Fe	Zn	Al	Sn	Calculated Velocity at Which Attack Began Feet Per Second	Calculated Rate of Loss in Attacked Area Mdd	Measured Max.[2] Decrease In Thickness, Inches
90:10 Cu Ni 0.7 percent Fe	89.06	9.84	0.71	0.20	....	....	16.4	149	0.008
90:10 Cu Ni 1.51 percent Fe[1]	88.4	9.6	1.51	....	....	....	16.2	147	0.006
90:10 Cu Ni 3.52 percent Fe[1]	85.7	10.2	3.52	....	....	....	16.2	194	0.011
90:10 Cu Ni 3.52 percent Fe[2]	85.7	10.2	3.52	....	....	....	23.6	57	0.003

[1] Annealed at 1300° F for 8 hours to precipitate iron.
[2] Quenched from 1700° F to hold iron in solution.

TABLE V

Copper-Nickel Alloy Condenser Tubes

ALLOY-DESIGNATION	Type of Alloy	CHEMICAL COMPOSITION, PERCENT Cu	Ni[1]	Fe	Al	Zn	Mn	Sn	Wall Thickness Mils	Tensile Strength psi	Tube Sheet Material	Time Under Test Months	Test Condenser Number
18 gage	90-10 copper-nickel	88.36	9.36	2.02	0.26	<.1	<.1	....	49	53,000	70-30 Cu-Ni 0.5% Fe	4.7	3
A		88.30	9.95	1.75	....	<.1	<.1	....	35	52,000	"	4.7	3
20 gage		86.81	11.24	1.40	....	....	0.49	....	35 49	52,200	"	4.7	4
D		88.52	10.46	0.72	<.01	<.1	0.30	....	35 49	51,100	"	4.7	3
E	70-30 copper-nickel	68.90	30.04	0.52	<.01	<.1	0.44	....	35 49	58,000	"	5.4	5 & 6
K		67.37	31.96	0.03	....	<.1	0.64	....	49	64,700	"	5.4	6 & 12
		68.70	29.73	0.12	<.01	<.1	0.43	0.91	35 49	61,700	"	4.7	1
MIL-T15005 SHIPS Amendment 15 Aug. 1951	70-30	65.0	29.0-32.0	0.40-0.70	Pb 0.05[2]	1.00[2]	1.00[2]	99.50[3]					
	90-10	....	9.0-11.0	1.00-1.75	Pb 0.05[2]	1.00[2]	0.75[2]	99.50[3]					

[1] By difference. [2] Maximum. [3] Copper plus sum of named elements, minimum.

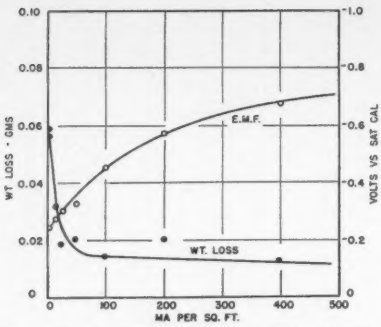


Figure 31—Cathodic polarization of 90-10 copper nickel in sea water at 7.7 ft. per sec. area 2.875 sq. in.

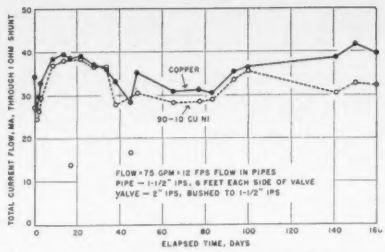

TOTAL CURRENT FLOW, MA. THROUGH 1 OHM SHUNT
COPPER
90-10 CU NI
FLOW = 75 GPM = 12 FPS FLOW IN PIPES
PIPE — 1-1/2" IPS, 6 FEET EACH SIDE OF VALVE
VALVE — 2" IPS, BUSHED TO 1-1/2" IPS
ELAPSED TIME, DAYS

Figure 33—Current flow between various pipe sections and cast iron valves with brass trim in sea water.

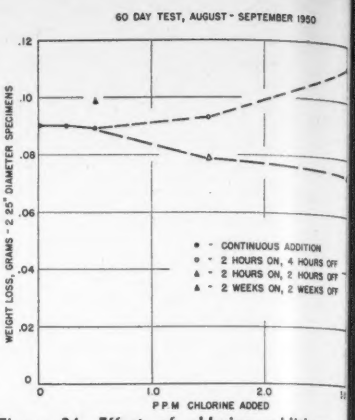

60 DAY TEST, AUGUST - SEPTEMBER 1950
WEIGHT LOSS, GRAMS - 2.25" DIAMETER SPECIMENS
● - CONTINUOUS ADDITION
o - 2 HOURS ON, 4 HOURS OFF
Δ - 2 HOURS ON, 2 HOURS OFF
▲ - 2 WEEKS ON, 2 WEEKS OFF
P.P.M. CHLORINE ADDED

Figure 34—Effect of chlorine additions on weight losses of 90-10 copper nickel plus iron in slowly moving sea water at Harbor Island, N. C. 60-day test, August-September, 1950.

Figure 32—Valve and piping galvanic test set up at Harbor Island, N. C.

TABLE VI

Arrangement of Metals and Alloys in Galvanic Series in Turbulent Sea Water

MATERIAL	Steady Pot. Neg. to Calomel Half Cell —Volts
Zinc	1.03
Al 3S-H	0.79
Al 61S-T	0.76
Al 52S-H	0.74
Cast Iron	0.61
Carbon Steel	0.61
Type 430 Stainless Steel (Active)	0.57
Ni-Resist Type II	0.54
Type 304 Stainless Steel (Active)	0.53
Type 410 Stainless Steel (Active)	0.52
Ni-Resist Type III	0.49
Ni-Resist Type I	0.46
Tobin Bronze	0.40
Yellow Brass	0.36
Copper	0.36
Red Brass	0.33
Aluminum Brass	0.32
Composition G	0.31
Admiralty	0.29
90-10 Cu Ni% .80 Fe	0.28
70-30 Cu Ni % .06 Fe	0.27
70-30 Cu Ni % .47 Fe	0.25
Type 430 Stainless Steel (Passive)	0.22
A Nickel	0.20
Type 316 Stainless Steel (Active)	0.18
Inconel	0.17
Type 410 Stainless Steel (Passive)	0.15
Titanium	0.1
Type 304 Stainless Steel (Passive)	0.084
Hastelloy C	0.079
Monel	0.075
Type 316 Stainless Steel (Passive)	0.05

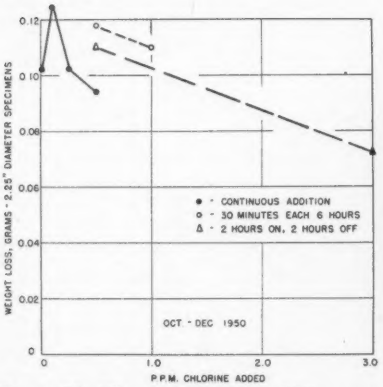

WEIGHT LOSS, GRAMS - 2.25" DIAMETER SPECIMENS
● - CONTINUOUS ADDITION
o - 30 MINUTES EACH 6 HOURS
Δ - 2 HOURS ON, 2 HOURS OFF
OCT. - DEC. 1950
P.P.M. CHLORINE ADDED

Figure 35—Effect of chlorine additions on weight losses of 90-10 copper nickel plus iron in slowly moving sea water at Harbor Island, N. C.

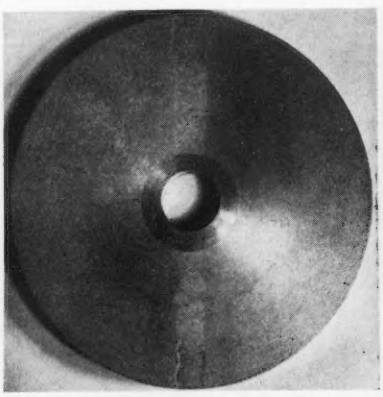


Figure 36—90-10 copper nickel with 70-30 weld.

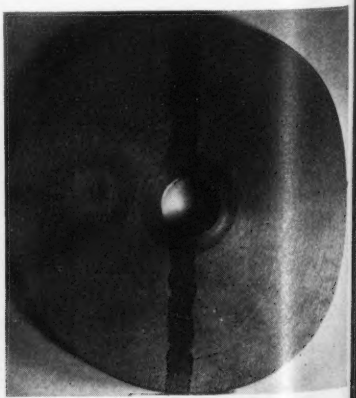


Figure 37—90-10 copper nickel with Monel weld.

contained 1.5 percent iron. The pipes were assembled with bronze fittings by silver brazing. The pipes were inspected after 9.8 months operation at 9 ft/sec. Pipes of 90-10 alloy containing 1.5 percent iron showed continuous corrosion films and were in good condition. One pipe section of 90-10 (0.87 percent iron) revealed bright metal for about 1.5 inches down from a fitting while another section showed a few eroded areas but otherwise the condition was good.

Two other branches consisting of 1¼ and 1½-inch pipes of 90-10 copper-nickel were inspected after six months test in sea water at 15 ft/sec. The test pipe sections, except one, were of 90-10 copper-nickel containing 1.5 percent iron. The single pipe section consisted of 90-10 with 0.87 percent iron. The general condition of these pipes was good. One pipe section of the high iron material (1.5 percent iron) was eroded uniformly for about 1 inch downstream of a globe valve, the attack not exceeding 0.005-inch in depth. The 90-10 (0.87 percent iron) pipe section showed slight inlet edge attack but otherwise was in good condition. Figure 29 shows the 90-10 copper-nickel pipe test system as installed at Wrightsville Beach, N. C.

Test results obtained to date for 90-10 copper-nickel alloy pipes parallel those obtained for laboratory test specimens and condenser tubes. The piping tests have shown the 90-10 copper-nickel alloy containing 1.5 percent iron to be superior to the low iron 70-30 copper-nickel alloy. The tests also indicate that the 90-10 alloy with 0.87 percent iron would be less satisfactory for ships' salt water piping systems than the same basic alloy with 1.5 percent iron.

High iron 90-10 copper-nickel alloys are more resistant to corrosion-erosion when solution heat treated. However, commercial tubing is supplied in a condition in which part of the iron is precipitated as an iron-rich phase. But even for this condition the conclusions of the preceding paragraph remain valid.

The 90-10 copper-nickel test piping system at Wrightsville Beach has been extended to include pipes up to 3-inch IPS. Welded fabricated fittings have been installed but no corrosion test data on these are yet available. However, the general appearance of the welds is as good or better than similar welds deposited with 70-30 copper-nickel electrodes. Welded fabricated fittings of 70-30 copper-nickel containing about 0.5 percent iron have been under test in sea water pipe lines for over two years with gratifying results.

6. Galvanic Behavior

Using apparatus described previously by one of the authors[18] the open circuit potentials and the cathodic polarization characteristics of the 90:10 cupro nickel alloys have been measured.

With this apparatus, sea water is made to flow across one surface of a test specimen which forms one of the walls of a rectangular channel.

Electrical connections are made to the outer surfaces of the specimens so that current from an external source may be applied to achieve polarization and so that potential measurements can be made with reference to a saturated calomel half cell introduced into the system. These measurements were made with a L and N potentiometer with an accuracy of ± 1 millivolt.

The open circuit potential measurements were made with a rate of water flow of 13 feet per second and at a sea water temperature of 79 degrees F. Results of such measurements on two specimens of a 90:10 alloy which contained 0.8 percent iron over a period of 475 hours are shown in Figure 30. Similar measurements on the series of alloys that contained up to 3.5 percent iron in different conditions of heat treatment showed the same final potential irrespective of iron content or heat treatment.

On the basis of such open circuit potential measurements the iron modified 90:10 cupro nickels have been located, as shown in the Galvanic Series for Sea Water shown in Table VI.

The cathodic polarization studies provided the data shown in Figure 31 for a 90:10 cupro nickel which contained 0.7 percent iron. Similar tests on an alloy which contained 1.5 percent iron showed substantially the same cathodic polarization characteristics. It will be observed that the alloy was polarized fairly readily as a cathode in turbulent aerated sea water. The relationship between applied current density, potential and corrosion rate indicated that whenever the potential of this alloy has been polarized to more than 0.35 volt vs a saturated calomel half cell substantially complete cathodic protection will have been achieved.

The iron modified 90:10 cupro nickels are polarized cathodically more readily than copper in turbulent sea water. From this it would be concluded that in galvanic couples with less noble materials such as steel or cast iron the extent of galvanic action would be less with the cupro nickel. This appeared as a practical problem when a question was raised as to whether it would be safe to substitute the cupro nickel alloy for copper in a salt water piping system in which it was desired to continue to use valves with cast iron bodies.

A test to answer this question directly was set up by allowing sea water to flow through test assemblies in parallel. In one system there was a cast iron valve with copper pipe each side of it and in another system there was an identical valve with the 90:10 cupro nickel (0.8 percent Fe) pipe each side of it. The pipes were insulated from the valves and the electrical connections in the galvanic couples were completed through 1 ohm shunts so that the galvanic currents generated could be measured during the progress of the tests.

This test set-up is shown in Figure 32. Results secured in this way are plotted in Figure 33. As indicated by its polarization characteristics the galvanic effect of the 90:10 cupro nickel alloy was less than that of copper. Consequently, it may be assumed that the substitution of the 90:10 cupro nickel alloy for copper in galvanic combinations with less noble materials will reduce rather than aggravate any galvanic corrosion problems that may exist.

The 90:10 cupro nickels are anodic to the 70:30 cupro nickels and may be expected to be more sensi-

TABLE VII

Results of Tests in Superheated Sea Water
Test Temperature 325° F
Duration: 54 Days. Velocity: 0.5 ft. per sec.

(Cupro-Nickel) MATERIAL	COMPOSITION[3] Cu	Ni	Fe	Zn	Mn	Corrosion Rates in Inches Penetration Per Year
90:10	89.06	9.84	0.71	.20	.19	0.0010[1]
90:10	87.85	10.07	1.7	(2)	.24	0.0015[1]
70:30	68.61	30.32	0.48	0.0	.51	0.0006[1]

[1] No pitting.
[2] Not reported.
[3] Method of determination not reported by supplier.

TABLE VIII

Results of Jet Impingement Test
With British Apparatus in Water Heated to 120° F
Jet Velocity: 10 ft. per sec. 3% by Volume Added Air. Duration: 26 Days.

MATERIAL	COMPOSITION Cu	Ni	Fe	Zn	Sn	Weight Loss in Mg. Per Day	Max. Depth Attack Inches
90:10 Cupro Nickel	89.06	9.84[1]	0.71	0.2	....	2	0.001
70:30 Cupro Nickel	69.05	30.26[1]	0.06	0.15	....	2	0.001
Admiralty Brass..	71.15	....	....	27.78[1]	1.01	29	0.029

[1] By difference.

tive to galvanic corrosion when coupled with much more noble metals and alloys. However, the 90:10 alloys have performed well in galvanic contact with the 70:30 alloys where the area relationships have been favorable—that is where the area of the 70:30 alloy was relatively small as in the case of 70:30 welds on 90:10 plates. The 90:10 alloy tubes—especially those containing 1.5 percent iron also performed well when installed in 70:30 cupro nickel condenser tube sheets. 90:10 cupro nickel baffles have also withstood corrosion satisfactorily in model heat exchangers fitted with 70:30 cupro nickel tubes and sheets with the water being outside the tubes. The 90:10 cupro nickel alloy in the form of piping has also performed satisfactorily in contact with standard composition M bronze valves and fittings.

7. Effects of Water Temperature

There has been a limited opportunity to observe the behavior of the 90:10 cupro nickel alloy in sea water heated much above normal temperatures.

TABLE IX

Results of Deposit Attack Tests in Quiet Sea Water at Harbor Island, N. C.
⅞-Inch Diameter Pile of Sand on 1½-Inch x 1½-Inch Test Pieces

MATERIAL	COMPOSITION Cu	Ni	Fe	Zn	Al	Sn	WEIGHT LOSS IN MILLIGRAMS Test 1 at 50° F Exposed 60 Days: Exposed Without Deposit	Exposed With Deposit	Test 2 at 70° F for 36 Days: Exposed Without Deposit	Exposed With Deposit	Test 3 at 81° F for 30 Days: Exposed Without Deposit	Exposed With Deposit
90/10 Cu Ni[3]	88.5	10	1.5	....	....	....	68	88[1]	38	38	44	36
70/30 Cu Ni Low Fe	69.05	30.26[2]	0.06	0.15	....	....	167	121	88	86	74	78
70/30 Cu Ni High Fe	68.92	30.16[2]	0.47	....	....	....	52	46	28	32	19	25
Admiralty Brass	71.15	....	....	27.78[2]	....	1.01	188	145	60	66	85	70
Aluminum Brass	77.30	....	....	20.42[2]	2.10	....	30	21	69	59	22	33

[1] Depth of attack under sand 0.0005 inch.
[2] By difference.
[3] Method of analyses not reported by supplier.

TABLE X

Results of Exposure of Specimens on Corrosion Testing Spools in Condenser Cooling Water Systems Where Polluted Waters Are Encountered

TEST LOCATION	Duration, Days	CORROSION RATE, INCHES PENETRATION PER YEAR 90-10 Cu Ni 0.7% Fe	90-10 Cu Ni 1.5% Fe[1]	70-30 Cu Ni 0.05% Fe	70-30 Cu Ni 0.4% Fe	Admiralty Brass	Aluminum Brass
Narragansett Electric Co., Providence, R.I.	360	0.0033 (No Pitting)	0.006 (Perforated)	0.0053 (No Pitting)	.....	0.0075 (Perforated)	0.004 (Perforated)
Condenser Water Box, Temp. 34° to 86° F. Dissolved O_2. 0 to 11 ppm.	137	0.0061 (No Pitting)	0.0062 (No Pitting)	0.0053 (No Pitting)	.....	0.0097 (No Pitting)	0.0074 (No Pitting)
H_2S, 200 to 0 ppm, pH 7.2 to 8.5. Dissolved Solids 7000 to 18,000 ppm.	347	0.0017 (No Pitting)	0.0027 (No Pitting)	0.0046 (No Pitting)	0.0013 (No Pitting)	0.0061 (Pitting to 0.022")	0.0010
Los Angeles Harbor Steam Plant, Condenser Water Intake Channel	213	0.004 (No Pitting)	0.0035 (Pitted to 0.009")	.....	.....	0.0034	0.0035
	269	0.0019 (No Pitting)	0.0014 (No Pitting)	.....	.....	0.0023 (Pitted to 0.014")	0.0018 (Pitted to 0.012")
United Illuminating Co., New Haven, Conn., Condenser Water Intake	364	0.0024 (No Pitting)	0.0015 (No Pitting)	0.0041 (No Pitting)	0.0009 (No Pitting)	0.0020 (No Pitting)	0.0008 (Some Dezincification)

[1] Specimens heat treated to permit precipitation of iron—not quenched.

TABLE XI

Results of Aspirator Type Jet Impingement Tests in Polluted Waters

TEST LOCATION AND CONDITIONS	MAXIMUM DEPTH OF ATTACK IN INCHES PER MONTH 90-10 Cu Ni 0.7% Fe	90-10 Cu Ni 1.5% Fe	Admiralty Brass	Aluminum Brass	70-30 Cu Ni 0.5% Fe	WEIGHT LOSS IN MG PER DAY 90-10 Cu Ni 0.7% Fe	90-10 Cu Ni 1.5% Fe	Admiralty Brass	Aluminum Brass	70-30 Cu Ni 0.5% Fe
Marion Generating Station, Jersey City, N.J. 36 Days Temp. 27° C (81° F)	.....	0.0012	0.0025	0.0035	0.0008	.....	1.1	2.3	2.7	1.0
Marion Generating Station, Jersey City, N.J. 37 Days. Temp. 5° C (41° F)	.....	0.0000	0.0005	0.0000	0.0000	.....	0.7	0.7	0.6	0.6
English Generating Station, New Haven, Conn. 30 Days. Temp. 45° F	0.0000	0.0000	.....	.....	....	1.6	1.4	....	.....	.....
English Generating Station, New Haven, Conn. 40 Days. Temp. 65° F	0.023	.....	0.005	0.009	0.002	13	.....	5	9	4
English Generating Station, New Haven, Conn. 30 Days. Temp. 66° F	.....	0.03	0.008	0.005	0.018	.....	9	9	12	23

However, one test was made in a special process in which the specimens were in contact with sea water heated under pressure to a temperature of 325 degrees F. The results assembled in Table VII show that this alloy can be expected to retain good resistance to corrosion by sea water at temperatures well above normal.

One set of jet impingement tests with the British apparatus was carried out at the Harbor Island Test Station using sea water heated to 120 degrees F. These results are shown in Table VIII and confirm the ability of the alloy to withstand impingement attack by sea water at temperatures higher than normal which cause severe acceleration of attack on Admiralty Brass.

8. Effects of Deposits

Because some copper alloys are susceptible to accelerated attack as a result of concentration cell effects under and around deposits of one sort or another an effort has been made to study the behavior of the iron modified 90:10 cupro nickel alloys under such circumstances.

G. L. Bailey[2] devoted some attention to this feature in his paper and reported that tests for deposit attack in stagnant salt water had shown that the 90:10 cupro nickel alloys were resistant to this sort of damage if the iron content were under 3.5 percent.

The conditions of relatively quiet exposure in sea water at Kure Beach and in the inlet at Wrightsville Beach, already described, provided some opportunity for concentration cell effects to develop under silt deposits and around the insulating fastenings. The absence of appreciable corrosion under these circumstances, as shown for example by Figure 1, may be taken as evidence that these alloys are not very susceptible to deposit attack. This was indicated also by some tests carried out at the Harbor Island Test Station when small piles of sand were placed on specimens held submerged horizontally in a tank through which clean sea water was allowed to flow very slowly. Results of these tests are shown in Table IX from which it will be seen that no significant deposit attack occurred under these conditions.

IV Behavior in Polluted Waters

Most of the investigations already described were carried out in clean sea water at Kure Beach and Harbor Island, North Carolina. It is known, of course, that good behavior in such unpolluted sea water will not necessarily be duplicated when alloys are exposed to attack by the peculiarly polluted waters of various and varying degrees of salinity encountered in many harbors. Water may be taken from such sources for cooling purposes in steam power stations, oil refineries and chemical plants.

Consequently, an effort has been made to accumulate data on the behavior of the 90:10 cupro nickel alloys in such polluted waters by three principal means—exposure of specimens in the water supply channels or condenser water boxes, operation of jet impingement test apparatus and installation of tubes in operating condensers. Results of all of these approaches will be discussed.

In Table X have been assembled results of the exposure of specimens on standard spools[19] in certain power plants where the cooling water is notoriously polluted and corrosive and has caused considerable trouble with corrosion of condenser tubes.

In Table XI are the results of impingement tests made with the aspirator type apparatus at the United Illuminating Company English Station at New Haven and at the Public Service Electric and Gas Company Marion Generating Station at Jersey City, New Jersey.

It is evident from the data in Tables X and XI that the corrosive characteristics of polluted waters vary through wide limits not only from location to location but at the same location at different seasons and in different years. It is not too surprising, therefore, that it is difficult to detect definite trends of alloy composition effects with a limited amount of data. About all that can be said is that the 90:10 cupro nickels compare favorably with other condenser tube alloys and may well provide economical solutions to particular problems presented by polluted waters. The optimum iron content may vary from one location to another. Where water velocities are low the lower range of iron content—e.g. under 1 percent—may be advantageous with respect to lesser susceptibility to pitting. On the other hand, jet impingement tests by the British Non-Ferrous Metals Research Association have shown that where the Copper Corrosion Index[20] of the water is on the high side the higher iron content alloys are much more resistant to impingement attack. Some results of British tests comparing 90:10 alloys of two iron contents are given in Table XII. These results of tests by the British Non Ferrous Metals Research Association[20] have formed part of the basis for their conclusion that where polluted waters having high copper corrosion index numbers are encountered the iron content of the 90:10 cupro nickel alloy should be on the high side—e.g. 1.5 percent or more—to insure adequate resistance to impingement attack when high velocities may be encountered.

The possible usefulness of the 90:10 cupro nickel alloys indicated by these data has been confirmed by the practical use of the 90:10 alloy as a condenser tube in plants handling polluted waters. Some typical reports of such trials are quoted below.

The first large scale installation of 90:10 cupro nickel tubes in this country was made at the Montaup Electric Co., Fall River, Mass. Some 80,000 pounds of 90:10 cupro nickel tubes containing about 0.7 percent iron were used under conditions where Admiralty brass in another condenser showed considerable corrosion within one or two years. Trial installations of aluminum brass and aluminum bronze tubes had shown poor performance of these alloys. The high iron 70:30 cupro nickel (0.5 percent iron) tubes performed well in trial but not much better than the 90:10 which was finally selected. These 90:10 tubes have given excellent service in this condenser and remain in satisfactory condition after use for four years, which is, of course, not long enough to establish their ultimate superiority over other materials.

In a report to the ASME Special Research Com-

mittee on Condenser tubes in 1950[21] E. F. Walsh of the Narragansett Electric Company, Providence, Rhode Island, reported on trials of several condenser tube alloys and stated that 90:10 cupro nickel tubes containing about 0.8 percent iron had been giving excellent service—there had been no evidence of pitting and the rate of thinning had been exceptionally low (for further data on this water supply see Table X).

Mr. Walsh rated the 90:10 alloy as superior to the 70:30 cupro nickels, aluminum brass, Admiralty brass and aluminum bronze. One trial lot of 90:10 tubes with 0.84 percent iron has been in service for over four years with no failures while another lot with 1.3 percent iron has shown no failures in 2½ years. At the same meeting A. M. Plant of the United Illuminating Company, New Haven, reported on some trials of 90:10 cupro nickel tubes with iron ranging from 0.75 to 2.0 percent. He said that they showed considerable promise with very low scale build up and freedom from pitting in these tests but had not come up to their expected performance in large scale tests with the alloys at the low end of the iron content range. For further data on this water supply see Tables X and XI.

At another meeting of the ASME Special Research Committee on Condenser Tubes in November 1951, W. L. Chadwick[22] of the Southern California Edison Company reported on trials of several condenser tube alloys in the polluted waters at their power stations near Los Angeles. Among these was the 90:10 cupro nickel which was rated superior to Admiralty brass and aluminum bronze and was given an over-all rating as being the preferred material for this service. The 90:10 cupro nickel which contained about 0.7 percent iron was considered to be superior to the same alloy with 1.5 percent iron in this water since the latter developed pits to a depth of about 0.005-inch during a 27,000-hour test period.

At this meeting also H. A. Todhunter[22] discussed the performance of materials in condensers at the Harbor Steam Plant of the City of Los Angeles Department of Water and Power. (For additional data re this water see Table X.)

At this plant 90:10 cupro nickel tubes which contained 0.8 percent iron appeared to suffer some initial corrosion but the rate of attack slowed down considerably and while this alloy is now rated inferior to 70:30 cupro nickel with 0.5 percent Fe it is considered to be a promising material for this service. It is definitely superior to Admiralty brass and aluminum bronze and at least equal to aluminum brass.

In reviewing the general situation with respect to the performance of condenser tube alloys in peculiarly polluted waters one must reach the conclusion that the ultimate selection of the most economical alloy for a particular service must be based on results of specific trials in the waters in question.

Available data on the iron modified 90:10 cupro nickel alloys indicate they are promising materials for such services and may prove to be most economical in many cases. Optimum iron content for polluted water service will have to be established by specific trials and probably will be influenced by the greater resistance to impingement attack at the high end of the iron content range—e.g. 1.5 percent—and the greater resistance to pitting at the low end—e.g. 0.8 percent. The velocity or erosive conditions to be encountered will presumably affect the choice on the basis of these considerations.

So far as occasional contact with polluted waters is concerned, such as might be the case with ships operating in polluted harbors from time to time, it may be concluded that the 90:10 cupro nickel alloy is no more vulnerable to damage of this sort than the other condenser tube compositions for which it may be substituted, including the 70:30 cupro nickels of either low or high iron content.

V Effects of Chlorination

Because it is common practice to add small amounts of chlorine to control fouling and sliming in salt water cooled heat exchangers and piping it became desirable to discover whether the corrosion resistance of the 90:10 cupro nickel alloy would be affected adversely by such chlorination treatments.

Specimens were exposed in the weir boxes of a testing system operated at the Harbor Island Testing Station. These individual wier boxes received the discharges from individual pipe systems which carried sea water into which chlorine had been introduced in controlled amounts either continuously or in accordance with some cycle. Results of such tests are shown graphically in Figures 34 and 35. Two specimens were exposed in each run. The points plotted are for average value of two specimens.

It will be observed that continuous additions of chlorine in the amounts required to control fouling and sliming had a negligible effect on the corrosion of the iron modified 90:10 cupro nickel alloy (0.7 percent Fe). When there was intermittent treatment with higher concentrations of chlorine corrosion was not aggravated appreciably. Least corrosion occurred when the frequency of the cycles of chlorination was greatest.

In a similar series of tests an opportunity was provided to observe effects of chlorination of sea water on 90:10 cupro nickel alloys of different iron contents. Results are given in Table XIII. From the data in Table XIII it would appear that the alloy of higher iron content was more sensitive to free chlorine in sea water and in this respect was inferior to the alloy of lower iron content as well as to the 70:30 cupro nickel alloy which was scarcely affected. Presumably some care should be exercised to avoid over chlorination of sea water where 90:10 cupro nickel tubes of high iron content—e.g. 1.5 percent—are installed.

TABLE XII

Results of British Jet Impingement Tests of 90-10 Cupro Nickel Alloys in Water of Different Copper Corrosion Index Numbers[1]

COPPER CORROSION INDEX NUMBER OF WATER	DEPTH OF IMPINGEMENT ATTACK INCHES PER MONTH	
	90-10 Cu. Ni. 0.7 Percent Fe	90-10 Cu. Ni. 2 Percent Fe
8.3	0.0004	.....
10.0	0.011	0.000
12.0	Perforated (0.05″)	0.000
15.6	Perforated (0.05″)	0.000

[1] Data courtesy of British Non-Ferrous Metals Research Association.

VI Behavior in Other Corrosive Media

While the 90:10 cupro nickel alloy was developed primarily to resist attack by salt water, the nature of its composition is such that it can be expected to resist corrosive attack in many other environments. In the absence of data with respect to specific media for which information on the behavior of copper and 70:30 cupro nickel is available, a rough estimate of the probable behavior of the 90:10 cupro nickel alloy can be secured by interpolation on the basis of a straight line relationship between the extent of corrosion and the nickel content of the alloy.

A large number of plant corrosion tests have been made in connection with specific process corrosion problems. Data from these tests are too voluminous to be included in the present paper but will be published separately within the next few months.

By way of particular comment it may be noted that as compared with the 70:30 cupro nickel alloy the 90:10 alloy is greatly inferior in resistance to such media as hydrogen sulfide, ammonia and hydrochloric acid as they are encountered in petroleum refining processes. It is also greatly inferior to the high zinc brasses in resisting attack by hydrogen sulfide at elevated temperatures. Consequently, the 90:10 alloy will have limited usefulness in petroleum refineries where attack by these chemicals

TABLE XIII

Effects of Chlorination of Sea Water on Corrosion of 90:10 Cupro Nickel Alloys of Different Iron Contents

Velocity 0.5 ft. sec.

Corrosion Rates in Inches Penetration Per Year

Test A—62 Days. May-July, 1951—Harbor Island, North Carolina

ALLOY	Untreated Sea Water	0.25 ppm Cl_2 Continuous	0.5 to 1 ppm Cl_2 Added 1 Hour Out of 6	0.5 ppm Cl_2 Added ½ Hour Each 8
90:10 Cu Ni 0.7 percent Fe	0.0023	0.0036	0.0031	0.0024
90:10 Cu Ni 1.5 percent Fe	0.0027	0.0055	0.0047	0.0028
Admiralty Brass	0.0029	0.0052	0.0059	0.0039
Aluminum Brass	0.0012	0.0026	0.0007	0.0014
70:30 Cupro Nickel (0.4 percent Fe)	0.0011	0.0010	0.0008	0.0008

Test B—132 Days. July-December, 1951—Harbor Island, North Carolina

ALLOY	Untreated Sea Water	0.25 ppm Cl_2 Continuous	1 ppm Cl_2 Added 1 Hour Out of 6	1 ppm Cl_2 Added 1 Hour Out of 12
90:10 Cu Ni 0.7 percent Fe	0.0009	0.0024	0.0018	0.0011
90:10 Cu Ni 1.5 percent Fe	0.0009	0.0047	0.0032	0.0027
Admiralty Brass	0.0015	0.0039	0.0039	0.0039
Aluminum Brass	0.0005	0.0009	0.0009	0.0010
70:30 Cupro Nickel (0.4 percent Fe)	0.0005	0.0006	0.0005	0.0005

TABLE XIV

Chemical and Mechanical Properties of 90-10 Copper-Nickel Alloys

MATERIAL		CHEMICAL COMPOSITION				T.S.	Y.P.	Y.S. 0.1% Offset	Elong. in 2-in.	Red. of Area	Hardness	Bend Test	
SIZE, INCHES	Nominal[2] Size, Inches	Cu	Ni	Fe	Mn	Lb. per Sq. In.			Percent		Rockwell "B"	Maximum Angle Degrees	Elong in 1-Inch Percent
TUBING													
¾"	1.050 O.D.	87.84	10.24	1.54	0.37	72500	68300						
1"	1.315 O.D.	87.82	10.27	1.53	0.38	62500	57600						
1¼"	1.660 O.D.	87.74	10.54	1.52	0.20	47700	18600						
1¼"	1.660 O.D.	88.50	10.21	0.87	0.42	76600	55900						
1½"	1.900 O.D.	88.19	10.23	1.39	0.19	47400	20100						
1½	1.900 O.D.	88.58	10.29	0.69	0.44	69400	53500						
2	2.375 O.D.	87.89	10.19	1.54	0.38	69400	60600						
SHEET													
	⅛ hot rolled	87.15	10.74	1.79	0.32	52200		27400	30.7		47-48	180	12.0
	⅛ cold rolled	87.08	10.84	1.76	0.32	56600		47200	21.5		66-67	180	10.0
	¼	88.48	10.30	0.95	0.28	57700		50100	14.5		66-67	180[3]	
PLATE													
	½ hot rolled	87.23	10.65	1.78	0.32	53400	44700		35.7		60-61	180	42.0
	¾ hot rolled	88.59	10.14	0.99	0.28	46100	33700		48.7		47-48	180	47.0
	¾ hot rolled	87.04	10.84	1.80	0.32	51900	38700		42.2		56-57	180	48.0
RODS													
1 dia.	Soft	88.30	10.22	1.05	0.43	45100	[1]	17600	50.1	79.1			
	Half-Hard					56500	[1]	53400	23.5	78.2			
	Hard					66400	[1]	58400	16.5	70.3			
1½ dia.	Hot Rolled	87.87	10.34	1.41	0.38	45900	[1]	23100	40.2	87.5	39	180	38.5
	Hot Rolled Annealed 1400° F 1 hr water quench					40200	[1]	15300	44.5	85.4	23-27	180	35.5
	Hot Rolled Annealed 1400° F 1 hr. air cooled	....	....	....	....	46300	[1]	20000	41.5	82.8	38.40		

[1] At 5 percent extension under load. [2] All tubes 0.065 inch wall. [3] One fine transverse crack 0.15 inch long.

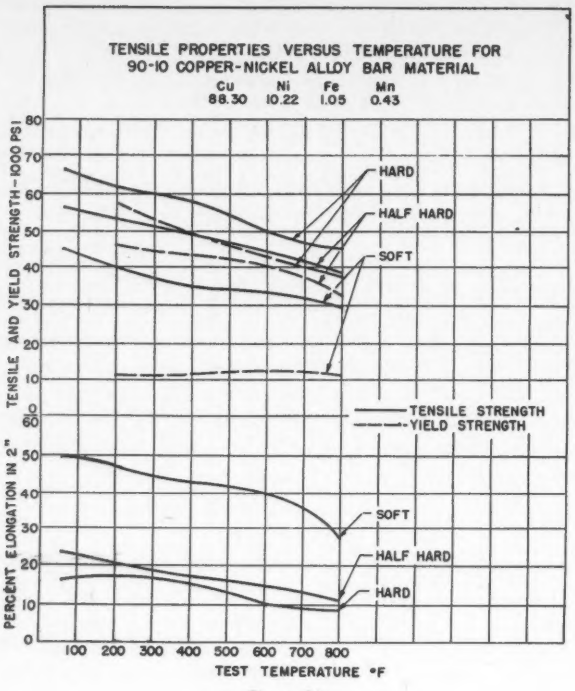


Figure 38

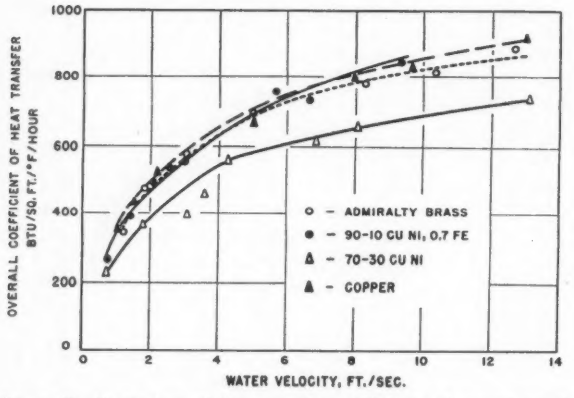

OVERALL COEFFICIENT OF HEAT TRANSFER
BTU/SQ. FT./°F/HOUR
○ – ADMIRALTY BRASS
● – 90-10 CU NI, 0.7 FE
Δ – 70-30 CU NI
▲ – COPPER
WATER VELOCITY, FT./SEC.

Figure 39—Comparison of heat transfer coefficients of several metal tubes—steam to water.

is a major factor in the selection of heat exchanger materials.

On the other hand, as compared with the brasses the 90:10 cupro nickel alloy is much less susceptible to season cracking[23] and dezincification and will benefit further from these advantages in the many environments where its other corrosion resisting qualities will recommend its use as in steam plant feed water heaters.

VII Welded and Brazed Joints

The brazed joints in the 90:10 cupro nickel piping test assembly already described have resisted corrosion entirely satisfactorily. This has also been the case with welds in water boxes on model condensers tested at the Harbor Island Test Station. Additional tests of welds are currently underway.

Specimens of a 90:10 cupro nickel which contained 1.5 percent iron and which were welded in one case with 70:30 cupro nickel metallic arc electrodes and in another case with Monel electrodes have been tested in the vertical spindle erosion testing machine shown in Figure 23. The appearance of these specimens after test for 60 days are shown in Figures 36 and 37.

Of particular interest is the absence of any evidence of localized corrosion along the margin of the welds, as a result either of the effects of the welding heat or of galvanic action between the 90:10 alloy and the more highly alloyed weld deposits. It will be noted from Figure 36 that the 90:10 alloy disc actually suffered less erosion in the region of highest velocity near the periphery than was suffered by the 70:30 cupro nickel weld deposit. This was due, no doubt, to the fact that the 70:30 cupro nickel weld deposit contained only 0.09 percent iron and, therefore, was less resistant to erosion than the high iron 90:10 alloy as shown, for example, by the data in Table III.

VIII Mechanical Properties of 90:10 Copper-Nickel Alloys

Tensile and other mechanical properties for tubes, sheet and rods of 90-10 copper-nickel alloys are given in Table XIV. The tensile properties at various temperatures as determined for standard .505-inch diameter specimens prepared from 1-inch bar stock of 90-10 copper-nickel alloy containing 1.05 percent iron are shown in Figure 38.

Fatigue tests were made of rotating cantilever specimens prepared from the 1-inch bar stock in three conditions of temper. The ratio of endurance limit to tensile strength ranged from .34 to .36. Thus, the endurance limit in rotating bending is nearly proportional to the tensile strength for the three conditions of temper. Alternating torsion fatigue tests (equal positive and negative stress) were also made of the materials. The endurance limit in alternating torsion was approximately the same for the three tempers, namely, 10,000 psi.

IX Heat Transfer Characteristics

The thermal conductivity of the 90:10 cupro nickel alloy is less than that of copper but superior to that of the 70:30 cupro nickel, Admiralty brass and aluminum brass.

Heat transfer tests between steam outside a tube and water flowing through the tube at different velocities were carried out under the direction of Dr. H. P. Simons at West Virginia University. Comparative data from these tests have been plotted in Figure 39. From this it will be observed that the over-all heat transfer rates through the 90:10 cupro nickel tube were even better than would have been predicted from the absolute values of the thermal conductivity of the alloy. The extent to which advantage may be taken of this property will be determined in most practical cases by the nature and importance of corrosion products or other films or scales which may exert controlling effects. At any rate, the alloy starts out at no disadvantage with respect to the common materials for which it might be

substituted insofar as its heat transfer characteristics are concerned.

X Present Status

A recent survey of the extent to which the iron modified alloy had already been put into service in this country showed a total production and use of over two million pounds during the past few years. Of this, approximately 50 percent has gone into steam plant heat exchangers where the record of performance has been very good.

On the basis of these experimental data, supported by many service records, it seems safe to conclude that the iron modified 90:10 cupro nickel alloy will prove to be a reliable and economical substitute for 70:30 cupro nickel and other alloys where resistance to corrosion and erosion by salt water is required—as in condenser tubes and piping sytems. It also will have a unique advantage where freedom from marine fouling organisms is also desired.

Acknowledgments

The authors express their appreciation to the Bureau of Ships for its support and continued interest in this and other corrosion investigations. They also acknowledge the very considerable help given them by their associates in carrying out many of the investigations that provided data summarized in this paper. Particular thanks are due Gordon Schreitz and J. L. Basil at the United States Naval Engineering Experiment Station at Annapolis, Maryland and H. T. Paterson and R. B. Teel at the Inco Marine Test Station at Harbor Island, North Carolina.

They are grateful to J. W. Freeman and A. W. Tracy of the American Brass Company and W. Lynes of the Revere Copper and Brass Company for contributions of specimen materials.

In addition they acknowledge the cooperation of their friends in the power industry who participated in the plant corrosion tests, particularly W. W. Broadbent of the Narragansett Electric Power Company, Phil Salmon of the Public Service Electric and Gas Company, Newark, New Jersey; A. M. Plant of the United Illuminating Company, New Haven, Conn. and H. A. Todhunter of the Los Angeles Department of Water and Power.

Finally they acknowledge the assistance of Mrs. E. B. Adams who drew many of the figures used to illustrate this paper and Miss Marguerite Bebbington who organized much of the data drawn upon to illustrate the several points under discussion.

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Why Power Companies Should Promote Corrosion Control*

By H. H. ANDERSON*

Abstract

Utility management is asked if it can afford to ignore its responsibility to promote corrosion control on its own systems in view of the extensive damage corrosion causes to iron, steel, lead cable and galvanized duct exposed to water. Engineering methods of minimizing corrosion damage are reviewed, with frequent examples of the varying corrosion problems found among utilities. References to discussions of various kinds of corrosion and the methods used to combat it in electric power, steam generating and other utility plants are given.

IT SEEMS that any customer who spends a quarter million dollars every month for electric power is given a special quota of adulation. Else why should a Shell Pipe Liner be asked to talk again to the Petroleum Electric Power Association after appearing on your program in Beaumont? There I tried to tell you something about the oil pipe line business and how electric power companies can give it better service. Today I will venture to tell you something about the electric power business and how it can reduce its operating costs and increase its revenues.

A customer—by observation of the externals of your business—can sometimes tell you how to give better service, but that customer may show his ignorance when trying to tell you about your internal problems. My zeal as a booster of corrosion control and of the National Association of Corrosion Engineers (NACE), prompts me to take the chance. Twenty-nine electric power companies are now members of NACE, including ten of the twenty-four member companies in PEPA. If I can convince the executives of other power companies that they have a vital enough interest in corrosion control to join the rest of us in NACE as corporate members, I will have performed a service for all of us.

The program says I am to tell you "Why Power Companies Should Promote Corrosion Control." To do this, I am going to discuss such control, first, in power generation, next, in power distribution and then in power marketing.

Corrosion in all its aspects has been scientifically estimated[1] to be costing the American economy at least 5½ billion dollars per year. Undoubtedly the electric power companies, operating as they do so much metallic plant, must be suffering their full share of this great loss. And underground corrosion alone is causing a loss of a billion dollars annually.[2] The electric power companies are deeply involved here, too. Such is obvious, because the Edison Electric Institute has reported that 100,000 miles of underground lead-sheathed cables are operated by the power industry.

What utility management, properly accountable to its stockholders, can afford to ignore its responsibility to promote corrosion control on its own system? I quote Mr. Turner White, Jr., of Union Electric of Missouri,[3] . . . "In any power plant . . . there are extensive surfaces of iron, steel, lead cable and galvanized duct exposed to soil and water, which will corrode if left unprotected—sometimes in an embarrassingly short time. Instances are of record of lead cable failure within a few months after installation. Such items as sheet piling, intakes, pipe lines, condensers, and the bearing piles which support many large structures and to which a grounding system is attached, are all subjects for consideration. If means to prevent electrochemical action were considered during the design period, great waste, cost, and inconvenience could be avoided."

Perhaps a few ideas about the causes and cures of corrosion should first be considered. In nature we find most metals in the form of compounds such as oxides, sulfides and chlorides. Audacious man has mined and refined these ores into his pure metals or alloys such as iron, steel, copper, lead, bronze, aluminum, magnesium and others. In doing this, man upset the electrochemical equilibrium of nature.

Mother Nature seems to resent this tampering by man with her metals and she straightway sets about to revert them to oxides, sulfides, chlorides, et cetera, so as to reestablish her age-old equilibrium. This reversion process is called "corrosion." Thus we see that man's metallic structures suffer corrosion because he has violated nature in their creation.

Corrosion is an electrochemical action and its obvious chemical change is always accompanied by a not-so-obvious flow of electric current from the corroding surface. This is due to a local battery action caused by junction of two different metals in an electrolyte, or of two different electrolytes contacting a single metal. Even the smallest exposed surface rust spot has all the needed elements of such a battery or electrolytic cell.

Corrosion of a metallic structure can be avoided or stopped in several ways. The first step to avoid it is proper choice, placement and coating of materials in the original design. A second way to avoid corrosion is by avoiding exposure of the structure to corrosive environment during operation.

But if the structure and its environment cannot be changed, corrosion still may be minimized or

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stopped in two principal ways, one of which is to cover or seal the metallic surface with an electrically impervious coating. This method is usually indicated for any exposure where the surface is accessible for application of such coatings. But where the surface is buried in water, soil or concrete, the easiest cure for corrosion is cathodic protection. This consists of smothering or reversing the outflowing battery currents of natural corrosion by application of stronger externally-generated currents which will reach the metallic surface via the water, soil or concrete. Such currents in small amounts may be generated by galvanic anodes of magnesium, aluminum or zinc.

Where larger amounts of cathodic current are needed, the indicated source is public service electric power—Mr. L.C.P. to you! But before we discuss how this great boon to humanity can be sold to the public to stop corrosion, let us consider some of the corrosion problems that are vexing you in power generation and distribution. The geographical spread of PEPA membership shows that your sources of energy include water-power, steam-power and internal-combustion engines. Thus I will discuss the three of them in that order. The source materials I have used are all articles in the NACE journal CORROSION.

The operator of a hydroelectric power plant has a host of corrosion problems because its environment is one of relatively high humidity, and many of its structures are continuously, intermittently or occasionally submerged. Corrective electrochemical balances are altered by changes in the alkalinity or acidity of the surface water with run-off conditions and this may be aggravated by variable dumping of industrial wastes. Hydroelectric plant corrosion problems and their solutions have been ably discussed by Mr. White[3] of Union Electric and Mr. J. A. Davenport,[4] advisor of the U. S. Corps of Engineers.

I will not attempt to repeat their discussions. Suffice to say that much experimentation has disclosed the values of coal-tar coatings, anodic metallizing and galvanic anodes. Union Electric has found that reachable penstocks, headgates, trash-racks, stop-logs and the like can be well-protected with carefully selected coatings. Inaccessible features such as steel guides and anchor bolts can be protected cathodically. Long-term tests of corrosion preventives for immersed metals are in progress under jurisdiction of the U. S. Corps of Engineers and the Panama Canal Authority.

The operator of a steam power station has another set of vexatious corrosion problems. Mr. J. A. Keeth[5] of Kansas City Power & Light has given a complete listing of these items. As to their causes, he first lists the items attacked by gases dissolved or entrained in liquids, such as the pitting of boiler and economizer drums and tubes and the internal pitting and general corrosion of steel pipe lines and the tubes of condensers, evaporators and heat-exchangers. Next he cites corrosion due to the decomposition of steam—especially of furnace waterwall and boiler tubes. Next is the attack by stack gases of air-preheater and economizer surfaces and of smoke-stacks and flues. And the waterwall tubes, for example, are also attacked by furnace slag.

Economizer tubes and boiler drums suffer corrosion fatigue and boiler feed pump casings and the joints in turbine casings are corroded by erosion. To complete the list, Mr. Keeth mentions graphite corrosion, copper-plating of steel, liquid corrosion and caustic embrittlement. Mr. Keeth also has ably discussed and prescribed cures for many of these ills. Considerable research[6] is being done elsewhere to reduce corrosion and metal attack in the steam-water cycle of steam power plants through control of the alkalinity of the water with ammonia.

Another source of trouble to the steam plant operator is corrosion of the bearings of turbo-generators. A careful study of this problem[7] has indicated the causes as stray currents and electrostatic charges that can be reduced or eliminated by use of earthing brushes for grounding the turbine shafts.

Operators of large internal-combustion engine prime-movers are faced with corrosion problems peculiar to the cooling-water systems and the exhaust systems, as well as valve, liner and crank-case troubles that may come from traces of sulfur in the fuel. A recent report[8] on the water-side deterioration of Diesel engine cylinder liners indicated that much of it can be controlled by chromate and other water-soluble inhibitors in soft cooling water.

The corrosion problems of power generation have at least the advantage of being concentrated and subject to intensive study, but those of power distribution are far-flung and often inaccessible. Besides the 100,000 miles of buried lead-sheathed power cables before referred to, your industry operates perhaps millions of miles of other distribution.

Consider, first, the larger power substations with their galvanized steel structures. Mr. Seibert Miller of Union Electric described[9] the deterioration of the galvanizing and how this can be prevented by application of properly-selected protective paint before it is too late. Mr. Miller also described[10] a method worked out for corrosion protection of power transformers by the flow-coat method of applying stripping media and protective coatings. This seems to be just as effective (and much cheaper) for completely covering radiator-type units in the field as if they were taken into a shop and vat-dipped.

The same method of protecting galvanized substation structures before described is just as effective for transmission-line towers. Methods have been developed also to determine whether or not corrosion is seriously damaging tower footings.[11] A survey of the large Detroit Edison system showed that only about half of their older towers were still being protected against underground corrosion by the original galvanizing. Cathodic protection under controlled conditions will provide the needed protection to the others.

Concerning deterioration of tower footings, one utility engineer[12] made the following comment: "Tower footings are set in various types of soils and are usually connected metallically to an overhead ground wire. This will create galvanic cells and cause accelerated corrosion on those footings set in

soils of low resistivity. The ground wire should be sectionalized by isolating each section with a strain insulator. Arching horns could be provided at each strain insulator."

We in Shell Pipe Line operate 18,000 circuit-miles of telephone and teletype circuits. Thus we are well acquainted with the atmospheric corrosion of overhead line hardware and guystrand. These problems and various corrective measures were well described in another CORROSION article.[13] The selection of correctly designed bands, rings, pins, bolts, braces, racks, clamps, clips, et cetera, their proper placement and a scientifically-determined program for replacements are essential for good service and optimum maintenance costs.

Only last month there was printed an article[14] indicating that the Rural Electrification Administration cooperatives are having their own corrosion problems in rural power distribution. One item specially mentioned is the galvanic corrosion of galvanized steel anchor rods that are electrically connected to copper grounding electrodes. (Even a pipeliner knows better than to bury zinc and copper adjacent in the ground and then wire them together!)

A significant observation on the whole subject of pole hardware was made by Mr. O. W. Oztrow of the Rural Electrification Administration. It was to the effect that the replacement costs are very high compared to the value of the items replaced; thus the use of any parts with a life shorter than that of the wooden structures is a serious mistake.

Last but not least is corrosion of the lead sheaths on the industry's 100,000 miles of buried power cable before referred to. For years cable operators in metropolitan areas have been plagued with electrolysis caused by stray currents from street dailway track systems. Now that so many of these carriers have been replaced with double-trolley or engine-driven motor-busses, the cathodic protection simultaneously afforded by these stray currents has been removed, thus exposing the previously protected local cable sheaths and pipe lines to the natural corrosive attacks of soil chemicals.

Many of the metropolitan joint industry committees previously established to deal with stray-current electrolysis are now continuing to cooperate for protection of the urban networks of cables and pipes from natural corrosion. However, the problems they must now solve are perhaps even more complicated than previously experienced.

NACE has a Technical Practices Committee, No. TP-16, studying electrolysis and corrosion of cable sheaths.[15] An outline of the objectives of this TP Committee No. 16 will best reflect the highly technical aspects of the problem. There are at present five subcommittees—some with numerous subgroups—each dealing with a part of the work. One is studying the use of protective bonds and insulating joints, drainage to railways and reverse-current switches and rectifiers. A second is investigating the processes of cathodic protection, concentration cells, galvanic action, alternating current corrosion and microbacteriological action.

A third group is studying protective potential and current criteria, ground-bed or anode design, galvanic anode systems, insulating joints and sheath ground cells. A fourth is working on standardization of field survey techniques and interpretations. A fifth group is studying protection of pipe-type cables and the sixth is studying all of the aspects of nonmetallic sheath coatings.

Typical articles in the journal CORROSION dealing specifically with lead-sheathed power cables concern: problems in general,[16] electrochemical factors,[17] salt as a medium of corrosion,[18] electrolysis surveys,[19] bonding against galvanic corrosion,[20] magnesium anode installations,[21] cathodic protection of 138-kv cable,[22] protective lubricants for cables in ducts[23] and protection by vulcanized coatings.[24] A recent article describes experience with 115-kv high-pressure oil-filled pipe-type cable.[25]

Gentlemen, as a pipeliner with corrosion problems that are relatively simple, I have the utmost sympathy for you corrosion-harassed electric power men! As an operating manager, if confronted with even a small share of all of your problems, I would promote corrosion control in my own organization with a vengeance. I can well understand why the Edison Electric Institute was so amenable to joining with nine other industries and NACE to sponsor the work of the Correlating Committe on Cathodic Protection.

This committee, of which I have had the honor during four years to be chairman, has just issued a consolidated report entitled "Cathodic Protection." To quote from the foreword, this committee was organized "to prepare and disseminate information about cathodic protection, and to encourage its beneficial use."

Thanks to the generosity of a group of oil pipe-line companies, 10,000 copies of this report have just been distributed to a wide cross-section of American industry, including every member (individual as well as corporate) of the National Association of Corrosion Engineers—in fact, the corporate members received ten copies each.

A table in this report shows that American industry today is operating about 1,720,000 miles of buried structures subject to underground corrosion that can be stopped by cathodic protection. Besides the 100,000 miles of electric power cable operated by your industry, there are 110,000 miles of communications cable operated by the Bell System, independent telephone companies and Western Union. Also, there are 460,000 miles of oil field and oil transportation pipe lines. 370,000 miles of gas pipe lines and 265,000 miles of water pipe lines. And also there are 418,000 miles of railroad track with much parallel buried signal cable.

Now I can fitfully address the power marketers among you. Here is a market for the sale of thousands more kilowatts of cathodic protection power to be delivered through rectifiers at 100-percent load factor on contracts that should run for the operating life of the structures protected. And in this report of the Correlating Committee, which you can supplement in many ingenious ways, you have a powerful sales medium that is already in the hands of

thousands of potential customers for cathodic protection.

I warn you not to underestimate the sales effort being exerted by manufacturers and distributors of galvanic anodes. Galvanic anodes have a definite value technically and economically for the protection of certain types of plant. But there are plenty of opportunities for beneficial application of public service electric power, in protecting the larger structures, that you will be well-advised to take advantage of.

It seems to me that selling cathodic protection to the buried-structure operator is much like selling safety to your own employees. You have the most compelling of all appeals, which is simply convincing him that he is the direct beneficiary of his own effort to protect himself and his worldly goods. This basic appeal of self-preservation is strictly humanitarian. Use of the report "Cathodic Protection" for this purpose can be made with clean hands.

All of the utilities in your PEPA have many miles of buried oil, water and gas pipe lines and communications cables within their service areas. All of these are potential beneficiaries of the proper application of cathodic protection and most are prospective customers of public service electric power for situations where galvanic anodes are not best adapted. Thus I expect you power marketers to say, "What are we waiting for?"

To return to my topic—**"Why** Power Companies Should Promote Corrosion Control," I feel that I have presented a large number of reasons—reasons that concern the generation executives, reasons that concern the distribution executives and reasons that concern the marketing executives. The operating men should be interested in reducing their headaches and in saving costs and the marketers should be interested in serving new customers, already half-sold on the use of more kilowatts, and in increasing revenues.

Add all of these reasons, and I must conclude that no alert power company general management or directorate can afford to neglect the aggressive and whole-hearted promotion of corrosion control.

Now let me suggest **"How** Power Companies Can Best Promote Corrosion Control." This is by aggressively supporting the work of the National Association of Corrosion Engineers—NACE. Many of your managements are doing this now, as is indicated by the present NACE membership. Of about 3,100 active or individual members, 270 of these work for electric power companies. Of NACE's 340 corporate members, 29 of these are electric power companies.

Considering PEPA's 24 member companies that aim to serve the oil industry, only 10 are corporate members of NACE. I can assure you that the 14 others are missing a bet in two respects. First, they are not getting the full value of NACE's great cooperative assistance in learning how best to stop corrosion of their own operating and distributing plants. And, second, they are not getting the full value of NACE's great camaraderie between corrosion-preventive suppliers and consumers.

Consider, now, that 115 oil and gas companies are members of NACE. Add to this the fact that oil and gas industry corrosion engineers were the zealous founders of the association. Now perhaps you can see that when a non-member power company's power engineer goes in to see an oil or gas company's corrosion engineer, the latter looks askance at the power man and wonders why his management is so shortsighted as to not more substantially support this great program of corrosion control which is so effectively spearheaded by NACE.

Joining NACE is so obviously beneficial to all concerned. The operating companies benefit by not having to include corrosion costs in charges for service. Suppliers of corrosion preventives benefit by the fair profit they can make from a legitimate business. Corrosion engineers benefit by continued gainful and respected employment. And the public benefits by not having to eventually pay corrosion costs.

Some of NACE's company members are little fellows. But why not? The manager of a small plant, too, can readily see that even a single new idea gained from NACE for reducing corrosion costs can many times overpay out the cost of a company membership.

Some top executives are slow to recognize the direct losses from corrosion and to connect its many indirect losses with their cause. Some of them are supersalesmen or business administrators—quite unfamiliar with the electrochemical mechanisms of corrosion. And some operators and engineers have insufficient data on the past costs of corrosion and on the effectiveness and payout of preventive measures to sell their need up the echelons of management to the top.

Effective control of corrosion can be achieved only by engineers trained in its technology. These engineers can do their best only if they solve their general problems cooperatively. The best forum in which to do this is the NACE. Management should recognize this opportunity and encourage their engineers to participate actively in the association. And management should display sympathy for their engineers' problems on the job and should encourage and support the NACE program.

Today, with a Third World War hanging like the sword of Damocles over our heads, a heavy defense program is greatly curtailing our civilian supplies of metals. Now, more than ever before, we will be forced to conserve the metals we have. Reduction of the ravages of corrosion will be a prime factor in this conservation. Thus, with conservation of metal now a **national requirement** as well as an economic desirability, the control of corrosion takes on a new importance.

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Corrosion by Fluorine and Fluorine Compounds*

By RALPH LANDAU*

Abstract

The extreme reactivity of fluorine paradoxically brings to its compounds their most attractive properties—resistance to chemical attack. Because it tends to displace other elements and because no other element is sufficiently reactive to displace fluorine, fluorine compounds become chemically inert. While fluorine is near oxygen and chlorine in the periodic table its 2.85 electronegativity is the highest known and makes it tend to displace them from their compounds. The heat of reaction of fluorine is much greater than for oxygen or chlorine, and while metals that resist oxidation also may resist fluorine, contaminants, particularly organic materials, may react so rapidly as to initiate ignition of backing metal.

Materials of construction useful in handling fluorine are given, with indications of their limitations as to concentration, heat and thickness and specific recommendations on general design factors are itemized.

General characteristics of the fluorocarbons, and some specific fluorocarbon materials are described.

Some safety recommendations are included.

ALTHOUGH FLUORINE has become of industrial importance only in recent years it is by no means rare and has been known as an element for nearly two centuries. Fluorine was first recognized by Scheele in 1771, three years before Lavoisier discovered oxygen, but its isolation baffled scientists for over 100 years. It occurs in considerable abundance in nature in such common minerals as fluorspar and cryolite.

Fluorine stepped out of the laboratory and became an industrial chemical on the first atomic energy projects. Since then considerable experience has been acquired in its successful handling. New applications for fluorine have been developing since the war and it promises to become a material of first-rank industrial importance.

Paradoxically, it is the extreme reactivity of fluorine that brings to its compounds one of their most attractive properties, that is, resistance to chemical attack. Since it is so reactive fluorine tends to displace other elements, chlorine and hydrogen for example, from their compounds. Once having done so, the resulting compound becomes chemically inert and immune to further attack, since no other element is sufficiently reactive to displace the fluorine.

Physical and Chemical Properties of Fluorine

At normal temperatures fluorine is a greenish-yellow gas, more yellow than chlorine in the same concentrations. It has a pronounced odor which can be detected in concentrations of only a few parts per million, the odor being somewhat different from chlorine and very distinctive and unpleasant. It can be compared to a relatively strong ozone odor associated with the characteristic odor of chlorine. The boiling point of fluorine is —306 degrees F (85 degrees absolute) below which temperature it is a bright yellow liquid.

It has been said so often recently that it is perhaps unnecessary to repeat that fluorine is the most reactive chemical element. It combines with practically every material under suitable conditions and with most materials spontaneously at room temperature. No organic material is completely resistant to fluorine except carbon tetrafluoride, which is the thermodynamically stable end product of the reaction of fluorine and carbon. Fluorine also reacts with most inorganic materials, except the inert gases and the metal fluorides in their highest valence state. Every system of fluorine and metal is thermodynamically unstable, but the reaction with most metals at room temperature is comparatively slow. At elevated temperatures reactions are vigorous and frequently self-sustaining. When initiated under the proper conditions, the reaction of fluorine and even the most resisitant metals can result in a flame like that of a welding arc.

The position of fluorine in the Periodic Table, adjacent to oxygen and chlorine, indicates that it can be expected to react in a manner similar to these well-understood neighbors, in kind perhaps but not in degree. A measure of the comparative reactivity of fluorine, chlorine and oxygen is the Oxidation Reduction Potential, or Normal Electrode Potential, which are as follows:

$\frac{1}{2} F_2 + e^-$	$= F^- + 2.85$ volts
$\frac{1}{2} Cl_2 + e^-$	$= Cl^- + 1.358$ volts
$\frac{1}{2} O_2 + H_2O + 2\,e^-$	$= 2\,OH^- + .401$ volts

Fluorine's electronegativity of 2.85 volts is the highest known and makes it tend to replace oxygen and chlorine from their compounds.

Likewise the heat of reaction for reactions in which fluorine participates is much greater than the heat of reaction with chlorine and oxygen. Comparative heats of reactions for these three elements are given in Table I.

From the corrosion standpoint, the extreme reactivity of fluorine, its high heat of reaction and its similarity in chemical behavior to oxygen and chlorine in kind but not in degree, suggest a number of general conclusions:

1. All metals are potentially vulnerable to attack by fluorine. Metals which show a superior resistance to oxidation may also resist fluorine and this parallel is borne out by such common examples as nickel and iron. Nickel resists oxida-

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tion better than iron and is also successfully used with fluorine.

2. In the presence of fluorine, chlorine and oxygen tend to be replaced in their compounds.
3. Contaminants, particularly organic, in a system containing fluorine may react so rapidly as to initiate secondary effects of greater consequence, such as the ignition and combustion of the backing metal.

Corrosion by Fluorine

Fluorine has been handled successfully for a number of years in such common metals as nickel, monel, copper, aluminum, magnesium and even steel. Comparative corrosion rates are given in Table II. In amplification of this data the following points are pertinent:

1. Protective Film

The ability of common metals to resist fluorine is the result of the formation of a protective film. A prime requirement for the formation of a stable protective layer is that it be adherent and insoluble. Such films are formed on those metals into the atomic distribution of which fluorine fits with minimum distortion of the lattice structure. Because of the relation of fluorine to oxygen and chlorine it may be expected that metals which form protective films with oxygen and chlorine will also do so with fluorine. The nickel-iron comparison has already been referred to.

The aluminum-oxide protective layer is one of the toughest known. Aluminum will combine with fluorine even more readily than with oxygen and the resulting aluminum fluoride layer is so strong that treatment with fluorine has been suggested as a means of providing a resistant finish for aluminum equipment. A similar approach to the finishing of magnesium is embodied in a recent patent which provides for dipping into solutions of fluorine compounds. Although magnesium forms no stable protective layer with oxygen its corrosion resistance towards fluorine is good, suggesting that the layer formed with fluorine is stable.

The presence of an impurity, such as oxygen, in fluorine may greatly modify the behavior of the protective film. One investigator who suspected his fluorine to contain oxygen found fluorine corrosion

TABLE I—Comparative Heats of Reactions*

Group	Reaction	Heat of Reaction
I	$F_2+2NaI=2NaF+I_2$ $Cl_2+2NaI=2NaCl+I_2$	$\triangle H=-240{,}000$ Btu/lb. mole F_2 $\triangle H=-105{,}000$ Btu/lb. mole Cl_2
II	$F_2+Ni=NiF_2$ $Cl_2+Ni=NiCl_2$ $O_2+2Ni=2NiO$	$\triangle H=-283{,}000$ Btu/lb. mole F_2 $\triangle H=-135{,}000$ Btu/lb. mole Cl_2 $\triangle H=-210{,}000$ Btu/lb. mole O_2
III	—C—H— $+F_2$=—C—F— + HF —C—H— $+Cl_2$=—C—Cl— +HCl —C=C— $+F_2$=—CF—CF— —C=C— $+Cl_2$=—CCl—CCl— —C—C— $+F_2$=2CF— —C—C— $+Cl_2$=2CCl—	$\triangle H=-184{,}000$ Btu/lb. mole F_2 $\triangle H=-42{,}000$ Btu/lb. mole Cl_2 $\triangle H=-193{,}000$ Btu/lb. mole F_2 $\triangle H=-60{,}000$ Btu/lb. mole Cl_2 $\triangle H=-162{,}000$ Btu/lb. mole F_2 $\triangle H=-29{,}000$ Btu/lb. mole Cl_2
IV	$2H_2O$ (gas) $+F_2=2HF+H_2O_2$	$\triangle H=-126{,}000$ Btu/lb. mole F_2
V	$CH_4+4F_2=CF_4+4HF$ $2CH_4+4O_2=2CO_2+4H_2O$	$\triangle H=-181{,}000$ Btu/lb. mole F_2 or $-722{,}000$ Btu/lb. mole CH_4 $\triangle H=-173{,}000$ Btu/lb. mole O_2 or $-345{,}000$ Btu/lb. mole CH_4
VI	$2H+F_2=2HF$ (gas) $4H+O_2=2H_2O$ (gas)	$\triangle H=-600{,}000$ Btu/lb. mole F_2 or $-600{,}000$ Btu/lb. mole H_2 $\triangle H=-970{,}000$ Btu/lb. mole O_2 or $-485{,}000$ Btu/lb. mole H_2
VII	$C_2H_2+5F_2=2CF_4+2HF$ $2C_2H_2+5O_2=4CO_2+2H_2O$	$\triangle H=-183{,}200$ Btu/lb. mole F_2 or $-916{,}000$ Btu/lb. mole C_2H_2 $\triangle H=-216{,}400$ Btu/lb. mole O_2 or $-541{,}000$ Btu/lb. mole C_2H_2
VIII	$S+3F_2=SF_6$ $2S+3O_2=2SO_3$	$\triangle H=-161{,}000$ Btu/lb. mole F_2 $\triangle H=-115{,}000$ Btu/lb. mole O_2

* Values calculated from thermal data of F. R. Bichowsky and F. D. Rossini, "The Thermochemistry of the Chemical Substances," Reinhold Publishing Corporation, New York, 1937, except items in Group III, which are from O. Bockemueller, "Organische Fluorverbindungen," F. Enke, Stuttgart, 1936.

TABLE II—Effect of Fluorine on Various Metals*

MATERIAL	Time of Exposure, Days	Temp., °F	Pressure of Fluorine, Lb./Sq. In. Absolute	CORROSION RATE		Remarks
				Mgm./Sq. Ft./Day	In. Penetration/Mo.	
Steel:						
Armco iron	20	167	14.7	33		
		930	14.7		11	Rate at end of first day
SAE 1010	6	167	14.7	1.25		Rate at beginning of test
				0.1		Rate at end of test
Low-silicon iron (0.004% Si)	1	392	7.35	187		
High-silicon iron (0.79% Si)	1	392	7.35	324		
Nickel and alloys:						
Nickel foil	2	140	0.44	0.5		Result appears too high
Monel weld	4	125	14.7			No evidence of corrosion or embrittlement
Monel tubing	10	250	19.7			No noticeable attack
Nickel sheet		930	14.7		0.006	Sample gained in weight after test
		1290	14.7		0.01	
Monel sheet		930	14.7		0.02	Sample cleaned after test to remove deposit
		1290	14.7		0.2	
Aluminum:						
Foil	6	309	14.7	0.41		Initial attack is higher than value given
Sheet		930	14.7		0.04	Max. of several tests
		1110	14.7		0.06	Max. of several tests
Copper and alloys:						
Foil	2	140	0.44	0.6		Result appears high
Wool		200-250	14.7			Sample caught fire
Sheet		930	14.7		0.2	
		1290	14.7		3	
Brass (70-30) sheet	2	140	0.44	1.3		Result appears high
Bronze	2	140	0.44	0.8		Result appears high
Cu-Ni (80-20)	2	140	0.44	1.0		Result appears high
Magnesium alloys:						
Revere MA sheet (1.2% Mn)	2	140	0.44	0.7		
Revere FS-1A sheet (3% Al, 1% Zn, 0.2% Mn)	2	140	0.44	1.5		
Revere J-1H sheet (6% Al, 0.7% Zn, 0.2% Mn)	2	140	0.44	1.4		
Chromium:						
Chrome plate (0.03 in.) on SAE 1020	1	302	14.7			No visible sign of attack

* The data given here are very approximate and probably do not give much more than an orientation on the properties of fluorine. All the systems are thermodynamically unstable, but protective films usually account for the low actual corrosion rates.

products on copper to be black and friable, suggesting cupric oxide. Such inter-lacing of the otherwise stable metal-fluoride layer with metal-oxide salt can only be considered to be disruptive.

2. Reaction With Silicon

Because of its greater reactivity fluorine tends to displace oxygen from silicon compounds forming silicon tetrafluoride, which is a gas at room temperatures. Fluorine also attacks the silicon in high-silicon irons, resulting in a condition similar to pitting. This explains the relatively high corrosion rates of steels containing more than 0.01 percent Silicon when exposed to fluorine.

The stainless steels in rolled or wrought form normally contain up to 0.5 percent silicon and are consequently more vulnerable to fluorine corrosion at moderate temperatures than the low-silicon carbon steels. Columbium-stabilized stainless (Type 347) is particularly vulnerable, probably because of the volatility of columbium-pentafluoride.

3. Surface Contaminants

Frequently, the reaction of fluorine with metals may be very limited when the surface is clean, but contamination with an organic material may result in a local reaction of such intensity as to raise the backing metal to the ignition point. If the surface contamination is small, the weight and cooling area of the backing metal may be sufficient to prevent ignition. Water vapor condensing on surfaces contacting fluorine can be a contaminant and all fluorine-handling systems must be not only clean of all usual contaminants and dirt but dry as well.

The results of experiments to determine the effect of contaminants in systems handling fluorine are given in Table III. The experiments were run under two sets of conditions, one with pure fluorine, the other with a mixture containing 20 percent fluorine in nitrogen. The results indicate that the dilute fluorine is substantially less reactive than the pure and that the precautions required with the dilute need not be so rigid.

4. Fluorine Firing

When fluorine emerges into the atmosphere through a leak, reaction with condensed water vapor forms sparks and flashes, though the pipe wall itself if sufficiently heavy may escape ignition. Once initiated, the combustion of metals in fluorine usually gives a flame of high intensity similar to that from a welding torch.

5. Inhibited Reactions

Some of the reactions of fluorine are frequently characterized by erratic rates. As an example, fluorine usually reacts vigorously with water, either in the liquid or vapor form, to form hydrofluoric acid and oxygen. Occasionally, however, inhibition has occurred so that water vapor may accumulate in the presence of fluorine until the reaction is suddenly initiated with explosive violence. The explanation for this inhibition is obscure but it is thought to be associated with the presence of surface contamination or other impurity, present perhaps only in minute amount.

Resistance of Non-Metallic Materials

A number of non-metallic materials when clean and dry exhibit moderate resistance to fluorine at atmospheric pressures. As with metals, surface contamination can accelerate attack greatly. Table IV presents the result of tests on the effect of fluorine on various non-metallic materials, and Table V the effect of fluorine on miscellaneous materials.

Materials of Construction

For the construction of equipment and piping to handle fluorine, nickel and Monel are equally resistant in clean systems. Copper, aluminum and magnesium are less resistant, roughly in the order named, though their physical properties frequently suggest the use of one of them for a special purpose, such as for valve seats. At atmospheric pressures and temperatures steel is frequently used, since it is feasible to use heavier thicknesses and accept greater corrosion than with other metals.

Although fluorine equipment and piping should be rigorously cleaned and dried before being put into service, it is wise to anticipate the occasional presence of water vapor, which with fluorine will form

TABLE III—Effects of Fluorine Flowing in a Contaminated System

TUBE MATERIAL	100 Per Cent Fluorine*		20 Per Cent Fluorine	
	3/8-In. Orifice	1/8-In. Orifice	Tank Pressure, Lb./Sq. In. Gauge	1/8-In. Orifice†
Clean brass	No reaction	No data	No data	No data
Clean copper	No reaction	No data	No data	No data
Clean stainless steel	No reaction	No data	No data	No data
1/4-in. oily brass (1/16-in. wall)	Heated to red heat, no burning	No data	No data	No data
3/8-in. oily copper	Burned as long as gas flowed	Burned as long as gas flowed	50	No reaction
3/8-in. oily stainless steel (1/16-in. wall)	Heated to red heat, no burning	Heated to red heat, no burning	No data	No data

* Tank pressure was 50 lb./sq. in. gauge.

† No data were obtained for the 3/8-in. orifice and 20 per cent fluorine.

TABLE IV—Effect of Fluorine on Various Nonmetals*

MATERIAL	Conditions	Results
CCl_4	Bubbled through 10% gas	No reaction
	Bubbled through 20% gas	Flames, mild explosion
Alumina (β)	3 hr., 392° F	No weight gain or surface effects
Alumina (activated)	Various conditions	Partial or nearly complete conversion to AlF_3
CaF_2 cement, baked dry with Na_2SiO_3	Approx. 400° F	No apparent attack
Carbon (amorphous)	212° F	No visible effect
Carbon (graphite)	212° F	Embrittlement
Glyptal	77° F	No burning if baked dry
Rubber (various)	Various conditions	Erratic; may or may not burn, but attacked to some extent in all cases, with increasing brittleness, cracking, and surface hardening over period of time
Transite	Various conditions	Resistant if clean
5% HNO_3 (70%) and 95% H_2SO_4 (96-98%)	100% fluorine at 1 atm, 4 hr. at room temperature	No noticeable change
100% H_2SO_4	100% fluorine at 1 atm, 100° F	Little attack; may get warm if impurities are present
95% H_2SO_4*	100% fluorine at 1 atm, 100° F, 1 hr.	Rapid temperature rise; some explosions as temperature rises
85% H_3PO_4	100% fluorine at 1 atm, 100° F, 0.1 hr.	No temperature rise

* The data given here are very approximate and probably do not give much more than an orientation on the properties of fluorine. All the systems are thermodynamically unstable, but protective films usually account for the low actual corrosion rates.

hydrofluoric acid. Monel has better resistance to hydrofluoric acid than nickel and in addition has superior mechanical properties and for these reasons is usually preferred over nickel as a material of construction.

Flanged joints should be held to a minimum in fluorine systems because even a minute leak under some conditions may lead to firing. Welds must be of the best quality, homogeneous and with good penetration and on completion should be cleaned of all flux and rough-polished. The argon arc process is usually preferred.

Valves for fluorine service are a difficult problem being vulnerable to leakage across the seats and at the valve stem. For low pressure service discs of Teflon seating on Monel have largely eliminated seat leakage. At higher pressures, discs of aluminum 2S seating against Monel have been successful. Sufficient differential hardness between disc and seat must exist to insure a gas-tight seal.

For low pressure service stem leakage can be avoided by the use of a Monel or copper bellows, silver-soldered to stem and body with joints subsequently nickel-plated. At higher pressures a packing made of a compressed mixture of powdered nickel, shredded asbestos and graphite has been used successfully.

For flanged joints at low pressures gaskets of soft copper or aluminum or of Teflon are satisfactory. At higher pressures sealing rings of annealed nickel between properly designed flanges are preferable.

Corrosion by Hydrofluoric Acid

Perhaps the most industrially-important fluorine compound is hydrofluoric acid. Like other acids in the presence of water the reactivity of hydrogen fluoride is governed by its ionic form. The tendency to ionize is increased with increasing concentration of water; consequently the reactivity of aqueous hydrogen fluoride is increased with increasing dilution. The lower volatility of hydrofluoric as compared with hydrochloric acid makes possible higher concentrations of the aqueous acid. Industrially, concentrated acid is handled more easily than dilute and in practice, in concentrations above 60 percent, is usually shipped in steel.

Some similarity may be expected between the reactivity of hydrofluoric and hydrochloric acids. Because of its lower molecular weight and the smaller diameter of its ion, hydrogen fluoride undergoes many of the reactions of hydrogen chloride but with greater activity.

Plastics generally have a more limited usefulness with HF than with hydrochloric acid, though there are many exceptions in commercial use. Ceramic materials are completely worthless. Most ceramic materials have as their basis the silicon-oxygen link and because fluorine tends to displace oxygen from silicon compounds forming the volatile silicon tetrafluoride, these materials are severely attacked by HF.

Somewhat as with fluorine, Monel is more universally applicable to the handling of aqueous HF over a wide range of temperature and concentration, than any other common metal. Nickel and copper generally show somewhat greater corrosion rates, particularly at the higher temperatures and lower concentrations. Aeration of the acid, and velocity and impingement effects, greatly accelerate corrosion on Monel, nickel and copper.

For concentrations below the 50 to 60 percent level, lead has been used with some success at room temperatures and at temperatures above this level when due allowance has been made for creep and similar temperature effects on the metal.

At concentrations below the 40 to 50 percent level and subject to the temperature limitations of the material, usually 120 to 150 F, rubber-linings have been used successfully. In the same concentrations Karbate has been extensively used for exchangers and pumps. Though this material is impregnated with a phenolic resin, it stands up well in practice, probably because of the limited area of resin exposed and possibly because the pores become filled with corrosion products.

Other metals that have been used with dilute HF subject to limitations of concentration and temperature are Hastelloy A, below 40 percent and 55 degrees C, magnesium below 40 percent and 25 degrees C; and silver, below 40 percent up to the boiling point. Carbon-filled phenolic plastics are in common use on dilute acid and polyvinylidene chloride materials give good service at moderate temperatures (50 C and below). Polyethylene bottles are invariably used with 48 percent (CP) acid.

For concentrations above 65 percent at temperatures up to 100 degrees F carbon steel has been used successfully. Stainless steel is usually found to be less satisfactory than carbon steel due to its silicon content. Used together with carbon steel, stainless steel may aggravate corrosion by electrolytic action. Cast steel will give fair service on pumps for concentrated acid, at moderate or room temperatures but is generally not used at concentrations below about 80-85 percent. Cast iron is not considered a safe material for hydrofluoric acid.

Interstate Commerce Commission regulations per-

TABLE V—Effects of Fluorine on Miscellaneous Materials*

MATERIAL	100 Per Cent Fluorine†		20 Per Cent Fluorine‡	
	⅜-In. Orifice	⅛-In. Orifice	Tank Pressure, Lb./Sq. Gauge	⅛-In. Orifice
Clean cotton hand towels (4 ply)	6 in.	3 in.	50 100	0 in. 0 in.
Clean laundered cotton cloth and wool suiting material backed with cotton (simulating clothing)	6 in.	3 in.	No data	No data
Clean cotton hand towels (4 ply), but contaminated with clean lubricating oil	Variable but burned under most conditions	Variable but burned under most conditions	No data	No data
Clean asbestos gloves	No data	Not safe at 3 in.	No data	No data
Clean natural-rubber gloves, smooth clean surfaces	No data	1 in.	No data	No data
Paper, pine wood block, spruce wood block, angle iron, granite, painted wood and iron	No reaction except when surfaces were rough or contaminated; then fired at 4 in.	No reaction except when surfaces were rough or contaminated; then fired at 4 in.	No data	No data

* Figures represent minimum distance required to prevent burning.

† Tank pressure was 50 lb./sq. in. gauge.

‡ No data were obtained for the ⅜-in. orifice and 20 per cent fluorine.

mit transport of 60 percent or stronger acid in steel containers previously passivated with slightly more dilute acid. The use of steel cylinders for shipping the anhydrous acid has been so extensive in recent years that it has been reported that the exterior of the cylinders is frequently more corroded than the interior. The magnitude of the corrosion rate of concentrated HF at temperatures as high as 50 degrees C is 0.015 to 0.020 inches per year.

Anhydrous hydrogen fluoride at elevated temperatures is successfully handled in nickel, Monel and copper. At temperatures of 500-600 degrees C the magnitude of the corrosion rate on nickel, Monel and Copper is 0.05 to 0.10 inches per year. Mixtures of hydrogen fluoride and steam at these temperatures have approximately the same corrosion rates on nickel and Monel.

Corrosion Resistance of Fluorocarbons

Although hundreds of thousands of organic fluorine compounds are possible and hundreds have been isolated, perhaps the most useful, after hydrogen fluoride and certainly the most promising are the fluorocarbons. These highly-, or totally-fluorinated compounds with carbon are usually chemically inert at normal temperatures.

In a general way it can be said that the character of an organic chemical compound is hardly changed when two or more of its hydrogen or chlorine atoms are replaced by fluorine, but that the stability of the resulting compound is greatly improved. The superior reactivity of fluorine permits it to displace hydrogen or chlorine; once having entered the compound no other element has the reactivity to displace it and the resulting compound becomes chemically inert—in the language of this symposium corrosion-proof.

Unlike the corresponding chlorine compounds, polyfluoride compounds cannot be hydrolyzed easily and oxygen cannot replace the fluorine atoms. As an example, ethylene dichloride $CH_2 = CCl_2$ is slowly oxidized by air; the corresponding fluorine compound ethylene difluoride $CH_2 = CF_2$ is stable to oxidation. The polyfluoride compounds are not only more stable than the corresponding chlorine compounds but the fluorine extends this stability to any chlorine atoms remaining in the compound. An example of this is the common refrigerant gas Freon F-12, CCl_2F_2, so stable that its chlorine will not react even with molten sodium.

Perhaps the best known fluorocarbon is Teflon, polytetrafluoroethylene, the polymer of the thermodynamically stable end-product of the reaction of ethylene and fluorine. Its chemical inertness derives from its complete fluorination, all four of the hydrogen atoms of the original ethylene having been replaced by fluorine. Teflon is of primary use as a joint filler, in gasket or packing form and as an electrical insulator which must at the same time resist chemical attack.

Less well-known perhaps are the fluorocarbon oils, completely or highly-fluorinated carbon compounds which find their greatest usefulness in filling those joints which move, i.e., the cylinder walls of pumps and compressors. Their physical property of fluidity at normal temperatures depends on the extent to which the polymerization of their monomers has been carried. Like Teflon and other fluorocarbons their chemical inertness derives from the presence in their molecular structures of two or more fluorine atoms.

Application

The design of a system to convey or contain fluids of the corrosivity of fluorine and some of its compounds depends not only on the rate of attack on the materials of construction but on their physical arrangement as well. An elementary example is the case of a pipe line gasket. In a line carrying dilute fluorine (20 percent or below) butyl rubber or neoprene makes a satisfactory gasket since contact with the gas is limited to the edge, and decay of the body of the gasket is relatively slow. If the same butyl or neoprene rubber were used as a pipe lining in the same system, its life might conceivably be less than one-tenth as much as when used only as a gasket.

Consideration of its physical arrangement as well as of its rate of attack by the corroding agent should be given to every proposed application of a material of construction in a corrosive system. Some of the aspects of physical arrangement which can accelerate or retard the corrosive action of the fluid handled are discussed below:

1. Physical Confinement.

This is the case of the pipe-line gasket discussed above. A joint-filler or packing completely or nearly completely confined will perish much more slowly than the same material with all its surface directly exposed to the corroding medium. In the case of the butyl or neoprene rubber gasket its physical quality of hardness or softness (its Durometer rating) can be as important a factor as its resistivity to dilute fluorine. If the material be too hard with reference to the seating area and the ability of the flange to deform the material to make it seal, penetration along the face of the gasket will result, with consequent rapid decay of the gasket material and, of course, leakage.

2. Capillary Channels and Pores.

Reference has been made to the tendency of fluorine to replace hydrogen in organic compounds, and the limitation this imposes on the use of most plastic materials. Graphite impregnated with phenolic resin has been used successfully with dilute hydrofluoric acid where glass has notoriously failed. The explanation of this apparent contradiction is that the resin in the ends of the pores or capillary channels is probably slowly attacked but that the corrosion products remain in the channels and offer a progressively increasing protection to the unattacked material laying behind. A somewhat similar phenomenon frequently occurs at the membrane side of silicate cement joints in ordinary acid brick-lined vessel construction.

3. Pipe Wall Thickness and Firing.

Where contamination with organic material or

water vapor exists a pure fluorine leak at atmospheric pressure can burn steel piping or equipment and the burning will continue as long as the supply of fluorine lasts. If the wall thickness and surface area of the pipe or equipment is sufficient to retard the rise of temperature, spontaneous combustion can be eliminated except in very unusual cases. In an economic choice between thin-walled construction of one material and heavy-walled construction of another of lower resistivity, the heavy-walled construction in some circumstances may be the better selection.

4. Abrasion and De-scaling.

Because the resistivity of metals usually results from a protective metal-fluoride layer, it is desirable to eliminate or minimize sliding contact or abrasion, which may de-scale or penetrate the protective layer. This is particularly pertinent in the design of valves.

Safe Practice

Although it hardly comes under the heading of corrosion it seems prudent in any discussion of fluorine to offer a few remarks on the subject of safe practice. Fluorine should under all circumstances be accorded the respect due an extremely hazardous chemical. The usual safe practices of identifying all fluorine-containing equipment with distinctive colors, of wearing goggles and protective clothing, of fireproof construction and of working at least two operators in any one area, should be carried out with thoroughness. The toxicity of fluorine and fluorine compounds has not been completely evaluated but the established tolerance level is very low. Fluorine on the exposed skin can produce a serious burn but specific and effective treatment is well-known.

Systems handling fluorine should be double-valved where tightness is important and pressuring the space between the two valves with an inert gas such as dry nitrogen may be desirable to prevent leakage. Containers of fluorine should never be heated.

NACE Requirements on Acceptance and Publication of Papers

(Quoted from "Guide for the Preparation and Presentation of Papers." National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.)

These instructions and suggestions govern preparation of papers for publication in CORROSION, and for presentation at meetings of the National Association of Corrosion Engineers. Papers may be submitted for consideration without invitation.

Papers submitted are subject to the publication rules and policies of NACE until released, or unless withdrawn by the author prior to presentation or publication. Papers shall not be a rewrite of material presented elsewhere. The same material shall not be rewritten for presentation or printing elsewhere, except that in some cases an article may be rewritten and pointed toward a particular industry without coming under this restriction. After publication in CORROSION, it is the policy of the Association to give permission to reproduce CORROSION articles verbatim. Such permission shall be requested in writing. Full credit must be given NACE as the original source.

Some Corrosion Experiences With Aluminum Crude Oil Lines *

By ALMONT ELLIS*

Abstract

Experience of Interstate Oil Pipe Line Company with 635-T6 extruded aluminum pipe substituted for steel pipe in Southwest Arkansas and the Louisiana Gulf Coast indicates that:

1) Efficiency of the inert gas arc welded joint is not very high, partial annealing of a zone about an inch from the weld proper having about 60 percent of the original ultimate strength of the untouched alloy.
2) Two quarter mile sections of 4-inch suction line laid in Arkansas failed in a little more than 25 months as the result of pitting at annealed areas.
3) One of two installations of 6-inch discharge lines pitted at points where iron sulfide scale accumulated and was replaced in a little more than three years. The second discharge line handles sour crude, natural gasoline, propane and butane and is still in use, but leaks at annealed areas indicate it will need replacing soon. Tests indicate exclusion of iron sulfide would eliminate practically all internal corrosion.
4) External corrosion at water crossings in Arkansas was observed in the form of 1/16-inch pits after 16 months.
5) A half mile of 4-inch line laid in South Louisiana marsh shows no evidence of external corrosion after 3½ years although partly submerged in salt water.

IN 1938, the Interstate Oil Pipe Line Company extended its pipe line system into Southwest Arkansas to gather the sour crudes and distillates produced in McKamie, Patton and Dorcheat-Macedonia Fields. These fluids, which contain as much as seven cubic feet of hydrogen sulfide per 100 gallons, brought about the rapid deterioration of steel piping and tankage. The increasing frequency of leaks in the gathering system made it necessary to replace much of the original piping within the first few years. The most severe corrosion occurred in field suction lines where the oil flow is sluggish and corrosion products and brine settle out to form galvanic cells with the steel piping. Under the most severe conditions, field suction lines have failed after as little as 24 months' service.

Since aluminum is resistant to hydrogen sulfide corrosion and had been used successfully as roofs for sour crude storage tanks for a number of years, it was decided to investigate the possibilities of using aluminum piping. During the latter part of 1947, discussions were started with several manufacturers of aluminum pipe. The Aluminum Company of America offered an early delivery of pipe in 4- and 6-inch sizes and expressed a willingness to cooperate by lending technical assistance for a testing program.

Preliminary laboratory tests indicated in high resistance of the 63S-T6 alloy to hydrogen sulfide corrosion. In addition, Alcoa personnel were very optimistic as to the resistance of aluminum to the extremely corrosive conditions in the marshy areas of South Louisiana. On the basis of this information it was decided to order 6½ miles of 4- and 6-inch 63S-T6 extruded aluminum pipe to test the resistance of this material to both internal and external corrosion.

The pipe was delivered in 40-foot lengths with standard dimensions of 4.5-inch OD and 0.237-inch wall thickness for the 4-inch pipe and 6.625-inch OD and 0.280-inch wall thickness for the 6-inch pipe.

One of the major problems in planning for the installation of aluminum pipe was that of field welding the joints. Aluminum alloys have been welded in shops by the "inert gas, arc welding" method for some time, but the process had not been used in the field. This process uses an alternating current of 60 cycle frequency with a higher frequency, 2 to 3 megacycles, superimposed on the 60 cycle frequency. A tungsten electrode is used that is not consumed, the filler metal being fed in and melted by the heat from the tungsten electrode arc. Argon gas is required to shield the weld puddle to prevent oxidation. In addition to these requirements, it is necessary to circulate cooling water through the torch holding the tungsten electrode to carry away the intense heat. Alternating current and cooling water are not available on the pipe line rights-of-way and it was evident that if the pipe were to be field welded, a special welding machine for the purpose would have to be developed.

The Hobart Brothers Company, with the assistance of Alcoa, designed and built an "inert gas arc" field welding unit. The machine had an AC generator, driven by a gasoline engine, that supplied the two frequencies of alternating current. Cooling water to the torch was circulated from the radiator of the gasoline engine. Argon gas was supplied to the torch from a bottle mounted in a rack on the machine.

The procedure in the field was to "roll-weld" three joints togther, and then tie in the 3-joint sections with a "bell-hole" weld. This was varied in the laying of 4-inch pipe in South Louisiana, where an entire one-half mile section was "roll-welded" from one spot. Due to the lightness and slickness of the pipe, it was easier to roll the pipe and pull it past the welder, than to move the equipment. This procedure is an important factor in marsh or swamp operations, since the cost of moving equipment is high.

The efficiency of the welded joint is not very high. The weakest point of the joint is about an inch away

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from the weld proper and is due to the partial annealing of the alloy from the high heat of the welding process. This annealing effect reduces the strength of the joint, in tension, to about 60 percent of the original ultimate strength of the untouched alloy.

The allowable working pressure of the pipe is set by the weakness of the annealed section and limits the working pressure of 6-inch pipe to a maximum of 1350 psi. The 6-inch pipe withstood a hydrostatic test pressure of 1000 pounds per square inch with no trouble of any kind developing.

Where the aluminum was joined to steel, the flanges and bolts were well insulated. Special insulating sleeves, gaskets and washers of Bakelite insulated the aluminum flange and bolts from the steel flange. The aluminum flange bolts were made more corrosion-resistant by anodizing them. This consists of placing the bolts in a hot sulfuric acid bath which forms a porous oxide film over the surface, then they are placed in a potassium dichromate bath which penetrates the oxide film and leaves a corrosion-resistant coating.

When minor changes in the lines were necessary and the special welding machine not available, two types of couplings were used. Style 39 Dresser Insulating Couplings were obtained with an extra set of gaskets so that both ends of the pipe would be insulated from the steel coupling. On special order, it was also possible to obtain aluminum Victaulic Couplings for this work.

Internal Corrosion

Five and one-half miles of 6-inch pipe and ½ mile of 4-inch were laid in the sour crude areas of Southwest Arkansas. Sections of lines which had been affected the most severely by internal corrosion were selected for replacement with aluminum.

For suction line service, two quarter mile sections of 4-inch were installed to replace badly corroded steel lines. After six months' service, special 40-foot flanged sections were removed from the lines and visual inspections made. A narrow band of pitting was found along the bottom of the entire lengths of pipe. The most severe corrosion, which consisted of 1/16-inch pitting, was found in the annealed area adjacent to the welds. No scrapers were run through these suction lines and corrosion products from upstream tanks and piping deposited at low points to comprise as much as 25 percent of the total volume of the line. At any place where scale was allowed to accumulate, corrosion was accelerated. Subsequent inspections at 6-month intervals showed that corrosion was continuing at a fairly uniform rate of ⅛-inch of penetration per year. The first failure occurred after 25 months service and the increased frequency of leaks within the next few months made it necessary to remove the suction lines from service.

For discharge service, two separate installations were made. The first installation consisted of a ½-mile section of 6-inch located downstream and fed by the aluminum suction lines. The stream through this line consisted almost entirely of crude oil. Although scrapers were run regularly, a hard black coating of scale was found to be adhering to the bottom 120 degrees of the pipe. Iron sulfide scale accumulated behind obstructions at welds and caused deep pitting. However, corrosion was less severe than in the suction lines, and it was 38 months before the first leak occurred. The line was then removed from service and replaced with steel.

The second discharge line, which is still in service, consists of five miles of 6-inch trunk line which handles the entire production from the sour crude area. In addition to crude oil, a large percentage of natural gasoline, propane and butane are moved through this section. Also, this line has longer operating schedule than the ½-mile section. After 30 months service, when it was necessary to relocate a portion of this line because of construction of an airport, an inspection showed the maximum depth of pits to be approximately 1/32-inch. The short length of pipe inspected contained only slight deposits of scale which, it was believed, accounted for the better corrosion experience. On the basis of this information, it was estimated that a much longer service life would be received from this installation. However, four months later, a leak occurred in an upstream portion of this line. As before, the pit hole was in the annealed area adjacent to a weld, but there was no opportunity to inspect the inside of the pipe for scale accumulations. Although this line is still in service, it is reasonable to expect that the replacement of the line will be necessary in the near future.

Some additional testing is still underway to determine the relative merits of various alloys and alclads for sour crude service. One special test section fabricated by Alcoa has an internal cladding of zinc. An inspection of this section revealed that the zinc was acting as a sacrificial anode to protect the aluminum underneath. As yet, it is not known how much additional service life would be provided by the cladding. Field and laboratory tests have indicated that the exclusion of iron sulfide from the aluminum lines would eliminate practically all internal corrosion. Possible solutions might be the construction of an all aluminum system, or the installation of filters at the upstream end of all aluminum lines. At the present, however, neither of these solutions appears practical and consequently is not being considered.

External Corrosion

In the sour crude area of Southwest Arkansas, the soil for the most part is sandy and external corrosion of steel piping has been negligible. There are, however, a few isolated locations where soil resistance is low and some trouble has been experienced in maintaining steel piping. It was through one of these "hot spots" that one of the 4-inch suction lines was laid for sour crude service. This line was buried except for the several points where it crossed a stream in a marshy area. At these points, the line submerged in water approximately four months of the year.

An inspection of this line after 16 months' service revealed external pits 1/32-inch deep at the stream

crossings. Samples of water and soil which were in contact with the corroded areas were collected for laboratory examination. The laboratory analysis indicated that soluble chlorides and heavy metals, such as iron and lead, in the acidic water (pH-3.7) were responsible for the pitting. Some slight etching of the surface was found underneath clay deposits on the pipe. Since this section was removed due to failure from internal corrosion within a few months, there was no opportunity to further observe external corrosion at this location.

The second installation to test the resistance of aluminum to external corrosion consisted of one-half mile of 4-inch laid along the Intracoastal Canal in South Louisiana. The crude handled in this area is sweet but the soil and salt water are very corrosive to steel. Unprotected steel pipe laid in this area develops leaks within two years and requires replacement in less than five years. This installation replaced steel pipe which had developed an excessive number of leaks after four years. Part of this line was buried in relatively high ground while the remainder was laid in the marsh where it is completely submerged in the salt water. After three and one-half years, no evidence of external corrosion has been found on any part of the line.

Conclusions

The use of aluminum piping for sour crude service has not been satisfactory. Line failures caused by internal corrosion have made it necessary to replace much of the aluminum piping after twenty-four to thirty-eight months service. The exclusion of iron sulfide scale and brine from the piping should eliminate this type of corrosion.

The one-half mile section of 4-inch laid in the salt water marshes of South Louisiana is still in service with no evidence of external corrosion after three and one-half years. Although the cost of this pipe in 1948 was fifty per cent greater than the cost of steel, the decreased cost of laying due to ease in handling the lighter pipe made the total cost of a bare aluminum line compare favorably with a protected steel line.

Sour Oil Well Corrosion
TP-1D—*Sour Oil Well Corrosion*★

By J. A. CALDWELL*

Abstract

The problem of corrosion in oil wells producing hydrogen sulfide has been a serious one for several years. Efforts to reduce the monetary losses due to this type of corrosion are now being intensified. In some areas, corrosion progresses at a rapid rate; tubing leaks or rod breaks may occur on an average of one every thirty days. Pumps may have to be pulled at frequent intervals, either because of corrosion of the pump or because of corrosion products from the pipe accumulating in the pump. Recent developments indicate that internal corrosion of casing in the vapor space is occurring in some areas.

A group for the study of sour oil well corrosion, designated Subcommittee TD-1D, was organized early in 1950. A preliminary survey of the extent of the problem has been made in the Arkansas, Kansas, and West Texas-New Mexico areas. A total of 8,215 sour-crude wells were reported; of this number, 3,618, or about 44%, were listed as being economically affected by corrosion. Costs of corrosion before the application of remedial measures ranged from an average of $270 per well per year in the West Texas-New Mexico area to $2000 per well per year in the Kansas area. Substantial reduction in the cost of corrosion has been effected in some cases by the application of various remedial measures.

THE problem of corrosion in oil wells producing fluids containing hydrogen sulfide has been a serious one for many years. In many wells in sour-crude areas the replacement of broken sucker rods and completely perforated tubing has been necessary at frequent intervals; in some cases the intervals have been thirty days or less, over an extended period of time. Pumps may have to be pulled at frequent intervals, either because of corrosion of the pump or because of corrosion products from the pipe accumulating in the pump. Failures of flow lines occur, resulting in waste of oil. Reports from certain areas indicate a recent realization of the extent of internal corrosion of casing in the vapor space.

Many of the severely affected wells are pumped to the limits of their productive capacities; therefore, production lost during down time for repairs cannot be made up, and the value of the oil thus lost must be charged against corrosion.

Oil wells which are classified as being in the "sour crude" category may produce gas containing from a trace to several percent by volume of hydrogen sulfide and one percent or more carbon dioxide. Water must be present in the well system for corrosion to occur; in most cases tubing, rod, and pump corrosion becomes serious only after water production has increased to a value of 50% or more of total fluid production. The oil itself is not corrosive. However, oils from different fields, and even from different wells in the same field, differ in certain characteristics which have important effects on the extent of corrosive attack; the wetting power of the oil on steel and its emulsifying action with water are two such characteristics.

Formation of Committee on Sour Oil Well Corrosion

Because of the need for a concerted attack on the problem of corrosion in sour-crude wells, a group for the study of this problem, designated N.A.C.E. Committee TP-1D, was organized early in 1950. This committee has as its objective the accumulation and analysis of data on sour oil well corrosion with a view to determining the extent of the problem and disseminating information as early as possible on likely methods of control. At the present time the committee has about twenty members.

Results of Circulation of Questionnaire

Copies of a questionnaire designed to obtain preliminary data on corrosion in sour-crude wells were sent by Committee TP-1D late in 1950 to one or more representatives of each of twelve producing companies. Information on the following areas was requested: Arkansas, Kansas, Rocky Mountain, and West Texas-New Mexico. Twelve completed questionnaires were received from a total of nine companies.

A total of 8,215 sour-crude wells was reported in the survey; of this number 3,618, or about 44%, were listed as being economically affected by corrosion. A break-down by areas showed that all of the wells reported from the Arkansas area, 72% of the wells reported from the Kansas area, and 36% of the wells reported from the West Texas-New Mexico area were listed as being economically affected by corrosion. No corrosive sour-crude wells were reported from the Rocky Mountain area.

Relative Severity of Corrosion

Results of the survey indicated that, in general, rods, pumps, and the inside of tubing are the items of well equipment most severely attacked, with the severity probably decreasing in the order given; there is some variance from this order for the individual areas. It was noted that corrosion of casing

★ Presented as a TP-1D Report
* Humble Oil and Refining Co.

both inside and outside, was listed by most companies as being of relatively low severity.

Methods of Control of Corrosion

Of the 3,618 wells reported in 1950 as being economically affected by corrosion, 942, or about 26%, were being treated with corrosion inhibitors. The inhibitors being used were formaldehyde, Kontol 118, Kontol 120, Corexit, Nalco 33, Noxit, and several additives and wetting agents the names of which were not specified.

No use of protective coatings was reported from Arkansas. They were in use for protection of rods and tubing in four wells in the Kansas area, and 25 wells in the West Texas-New Mexico area. One well was equipped with cement-lined tubing; all other protective coatings were air-dried or baked-on plastic.

There were 212 alloy rod strings, 133 alloy pumps, and 62 alloy tubing strings in service in the areas covered by the survey. It is probable that in some cases two or even three types of alloy equipment were in service in the same well; calculations from figures in the individual reports, however, indicate that a minimum of 337 wells had one or more items of subsurface equipment made of alloy steel.

Economic Aspects

Costs of corrosion in 73 wells in the Arkansas area prior to inauguration of a corrosion control program were estimated at $92,000 per year, or an average of about $1,250 per well per year. Cost of the control program, plus remaining corrosion, was estimated at $6,430 per year or about $100 per well per year.

Cost data are available for only 275 of the 1170 corrosive wells reported from the Kansas area. Calculations show that the cost per well per year before start of a control program was about $2,000; after start of the program it was about $225.

In the West Texas-New Mexico area the cost of corrosion was about $270 per well per year; after inauguration of a control program the cost was about $220 per well per year.

Conclusions Drawn From Results of Survey

From the available data it appears that:

1) Corrosion is more severe in sour-crude wells in the Arkansas and Kansas areas than in sour-crude wells in the West Texas-New Mexico area.
2) In general, rods, pumps, and the inside of tubing are the items of subsurface equipment most severely corroded.
3) Corrosion of rods, pumps, and tubing in sour-crude wells can be substantially reduced by mitigation methods presently available.
4) The use of corrosion inhibitors is considered by operators to be the most efficient method of control.

Recent Developments in Internal Casing Corrosion

The potential danger associated with a casing failure in a high pressure well from any cause has long been recognized, but the number of casing failures due to corrosion has been small. However, recent reports have indicated that internal casing corrosion in certain areas is a matter of considerable concern to the operators involved. Apparently corrosion occurs in the vapor space of the casing-tubing annulus in most cases. The cause of the corrosion is thought to be condensed moisture containing hydrogen sulfide and carbon dioxide; gas produced from typical wells in one field where this type of corrosion is known to occur contains one percent hydrogen sulfide and seven percent carbon dioxide. In the Slaughter and Wasson fields of West Texas, several hundred wells may be subject to this type of attack.

Volatile substances such as formaldehyde and anhydrous ammonia are being tested for their effectiveness in controlling vapor space corrosion; one operator has made a one-batch injection of ammonia into each of some twenty wells in one field, and another operator is preparing to start similar injections. Kontol 118 is being injected into a considerable number of wells for the same purpose; usually each batch is followed by copious quantities of produced well fluids in an attempt to distribute the inhibitor uniformly over the surface of the pipe.

Performance of Tubing Materials and Coatings

Steel pipe, plain or galvanized, and wrought iron pipe have been proved unsatisfactory under highly corrosive conditions in sour-crude wells. A string of nine percent nickel steel tubing in service thirty months in a well in the Howard-Glasscock field in West Texas was reported to have developed pits of depth equal to 30 percent of the original wall thickness and to have failed in several joints by cracking. The normal life of black pipe in this well is nine months. When it is considered that the cost of the nickel steel was about four times that of black pipe, it is obvious that little economic advantage was obtained.

Black pipe coated with air-dried or baked-on plastic has been tested by several operators in the Kansas and West Texas-New Mexico areas with unsatisfactory results in a majority of cases. In a few instances, notably in the Penwell field in West Texas, plastic coatings have shown savings even in pumping wells.

Plastic pipe is being tested for use as tail pipe below the pump in several fields in West Texas. The plastic collars of one installation were found to be severely abraded after six weeks in the well due to vertical movement of the tubing string associated with pump operation; tubing centralizers will be tried in an effort to overcome this difficulty. Several thousand feet of plastic pipe is being tested as flow lines in the same area; reports indicate satisfactory operation during the period of one year in which it has been under test.

Rod Materials and Coatings

Sucker rods coated with an air-dried or baked-on plastic have been tested in relatively few wells; the results to date are mildly encouraging. Nickel-plated rods are satisfactory but are high in cost when avail-

able. A test of solid aluminum rods is being made by one operator in West Texas; it is believed to be too early for conclusions to be drawn as to their value. Apparently Monel is a very satisfactory material for rods; a string of K-Monel rods is reported to have operated for a period of ten years with no failures in a well in the Howard-Glasscock field in West Texas.

Inhibitors

Because high-alloy steels are costly when available, and plastic coatings have, in general, been proved to reduce corrosion costs by only small amounts, it appears that the use of inhibitors is the most efficient method of control in sour-crude wells. Inhibitors of the neutralizing type, such as ammonia and soda ash, are unsuitable for use in these wells as a means of reducing corrosion of tubing, rods, and pumps because of the troublesome precipitate which would be formed upon contact with the produced water. Formaldehyde has been used in many wells in various fields, with varying degrees of success. Organic inhibitors of the adsorbed-film or oil-wetting type appear to be effective, and to be preferred by the majority of operators. These inhibitors do not cause the formation of scale, can be handled easily in the field, and are available at reasonable cost.

The proper application of inhibitors makes possible the use of black pipe, carbon steel sucker rods, and low-price pumps in very corrosive locations; this is especially important during the present shortage of alloying materials. Because wells vary in severity of corrosive action on subsurface equipment it is impossible to set an exact figure on the cost of inhibitors needed to reduce the corrosion to a satisfactory level. However, for practical purposes it is probably safe to say that severe corrosion in sour-crude wells producing 25 barrels of oil and 25 barrels of water per day can be reduced satisfactorily by the use of inhibitors presently available at a cost of one dollar or less per day.

Summary of Remedial Measures

Because pressures, rates of production of oil, water, and gas, wetting power of the oil, methods of production, acid gas contents of produced gas, and other factors may differ widely even among wells in the same field, it is probable that no simple rule for the alleviation of corrosion can be devised. Some of the steps which can be taken in various corrosive situations with promise of some degree of success are given below. No attempt has been made to list the steps in order of importance.

A) Internal casing corrosion.
   1) If feasible, set tubing on packer, fill annulus with sweet or inhibited sour crude.
   2) If not feasible to set packer use volatile inhibitor such as formaldehyde or ammonia or a proved polar organic inhibitor along with considerable quantities of pipe line oil. The frequency of treatment necessary with this method has not been determined, but should range upward from several months. If the well is subject to tubing, pump, or rod corrosion in addition to internal casing corrosion, inject an organic inhibitor along with considerable quantities of pipe line oil at such intervals as may be dictated by requirements for controlling corrosion of the tubing, pump, or rods.

B) Tubing corrosion.
   1) If feasible, inject organic inhibitor into annulus. This will take care of practically all pumping wells.
   2) If tubing of flowing well is to be set on packer coat inside of tubing with plastic*, or use organic inhibitor in stick form.
   3) Use plastic pipe below pump.

C) Rod corrosion.
   1) Use K-Monel, or 9-12 percent nickel steel when available.
   2) Use nickel-plated rods.
   3) Inject organic inhibitor into annulus.
   4) Coat rods with plastic.

D) Pump corrosion.
   1) Inject organic inhibitor into annulus.
   2) In design of pump give consideration to hardness, toughness, and corrosion resistance of various parts.

E) Flow line corrosion.

   If pressure is less than 100 lbs./sq. in. and temperature less than 150° F. use:
   1) Plastic pipe.
   2) Plastic lined steel pipe.
   3) Cement lined steel pipe.
   4) Transite or cement-asbestos pipe.
   5) Organic inhibitor.

   If pressure is more than 100 lbs./sq. in., or temperature more than 150° F. use:
   1) Plastic lined steel pipe.
   2) Cement lined steel pipe, if brine of suitable composition.
   3) Organic inhibitor.

Acknowledgment

The author wishes to acknowledge the cooperation of numerous individuals, both members and nonmembers, in the work of N.A.C.E. Committee TP-1D.

Note: Various types of plastics and plastic coatings vary tremendously in their response to changes in temperature and chemical environment.

Topic of the Month

Trifluorochloroethylene Polymer Resin Dispersion Films on Metal

By F. E. GUSMER*

TRIFLUOROCHLOROETHYLENE polymer (Kel-F) dispersions are applied to selected metal surfaces by spray. The dispersed phase consists of resin particles from approximately .2 to 3 microns in size, dispersed in an aromatic hydrocarbon (xylol). The dispersions are very stable but settle slightly on standing. Mild stirring returns the dispersions to their original form. Surface tension of the dispersion is from 30-35 dynes per cm. Resin solids vary between 27 and 40 percent. Two different molecular weight resins are available—high and intermediate. In this company's opinion, the intermediate molecular weight is better suited because little practical chemical resistance is lost and much gained in case of application, heavier single films and better flow when fusing. No primer is required. Each coat must be completely fused before applying another.

Metal Surface Preparation

In all successful applications made this company has emphasized smooth metal surfaces. All corners and edges to be coated must be rounded and without cracks, crevices or sharp-edged pits. No grease, dirt or old paint can be tolerated. At this writing, applying Kel-F Dispersions to copper or to copper alloys has not been successfully done by this company. Adhesion to iron, steel, various austenitic stainless steels and aluminum has been good.

Spraying

Both pressure pot or cup and suction spray cup methods are useful. Stainless steel spray gun needles and nozzles are of advantage. Thirty psi atomizing pressure and 12-15 psi fluid pressure for pressure spray systems and 35 psi air pressure on suction type cup guns is recommended.

The first coat is applied at 20-22 percent solids (employing reagent grade xylol for reduction). Subsequent coats are applied at 26-28 percent solids using the same reducer. Each coat, except the first, is applied to achieve approximately .75 mil thickness. Heavier films show a tendency to "mud-crack" and subsequent fusing does not remove "mud-crack" flaws in the film.

* President, A. Gusmer, Inc., Woodbridge, N. J.

Drying

Immediately after spraying the applied dispersion appears as a semi-transparent, wet coating. After a short period the xylol evaporates, leaving a light grey or white powder on the surface of the metal. All areas must show this white color before the piece involved is heated. The white Kel-F powder can be easily removed by contact. Care must be taken not to touch any coated area before fusing and cooling.

Fusing

In the event the coated piece is to be installed directly into an oven that has reached, or is held at fusing temperature, additional precautions include prior force drying by moving air or a short bake at 150-180 degrees F. This will insure complete removal of the xylol. Residual xylol in the film may cause blistering if the piece is immediately subjected to high temperatures. Each coated piece is heated to 425-435 degrees F metal temperature and held at that temperature for thirty minutes, each coat. After the required number of coats have been applied, the piece is held at fusing temperature, as given, for one and one-half to two hours. If the end use requires high gloss the fused piece while at, or above 400 degrees F, is plunged into cool water and allowed to chill therein. Slow air cooling results in a semi-gloss surface. Because large units ordinarily cannot be quenched in water, it follows that the coating thereon will lack high gloss. Fusing does not "cure" or dry the resin. The relatively high temperatures induce softening and melting together of the individual particles, thus partially liquefying them. This results in a homogeneous film. In addition, since Kel-F has very low surface tension, the hot semi-liquid coating tends to flow into irregularities in the metal surface, thus resulting in excellent adhesion. Temperatures above 500 degrees F degrade Kel-F if exposure is excessive. Fusing times longer than normal should not exceed 415-425 degrees F metal temperature.

Testing

The presence or absence of flaws in multiple coat films of Kel-F on metal are detected by electrical resistance meters. A sensitive ohmmeter is connected across the film—one lead to a bare metal area and the other, through a sponge, wet with 2% Na Cl solution, to the surface of the coating. The sponge is passed carefully over all surfaces of the

(Continued on Page 2)

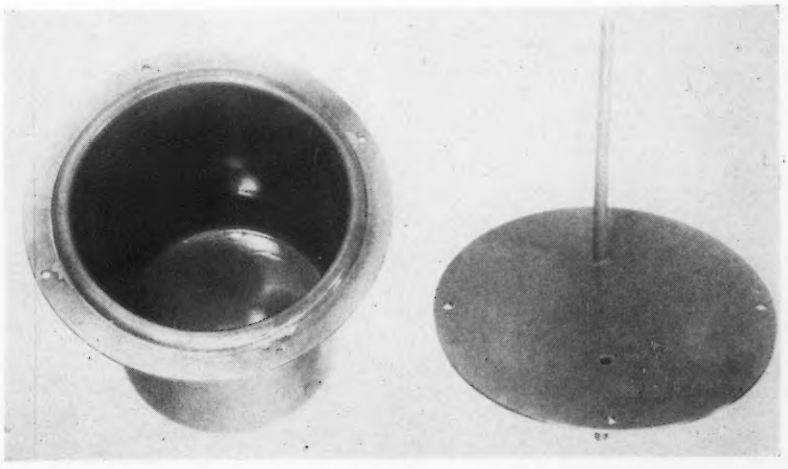

Figure 1—Kel-F dispersion coated stainless steel beaker for laboratory tests of highly corrosive materials.

Trifluorochloroethylene—

(Continued From Page 1)

area to be tested. Thin spots and discontinuities are indicated by lesser resistance readings on the ohmmeter. Normal resistance of a tight 6-8 mil film is above 5 megohms. Discontinuities usually indicate from 1000 to 10,000 ohms resistance.

Chemical Resistance of Continuous Film

Effect of Oxidizing Acids—**None**
Effect of Inorganic Acids—**None**
Effect of Organic Acids—**None**
Effect of Alkali Solutions—**None**
Effect of Salt Solutions—**None**
Effect of Halogenated Solvents—**Cause swelling**
Effect of other Organic Solvents—**None**
Resistance to heat—**to 325-350 degrees F.**
Water Absorption—**0.00%**
Burning Rate—**Nil**

Physical and Electrical Properties

Elongation—28-30%
Brittleness Temperature—Below —120° F.
Durometer Hardness—D scale 80
Thermal Conductivity — 1.44×10^{-4} $\frac{cal/cm^2/sec}{°C/cm.}$
Therm. coefficient Lin. Exp.—7×10^{-5} in/in/°C
Dielectric Strength—Step by Step .005" v/mil 5000
Arc Resistance—360 sec.

Conclusions

General chemical resistance is outstanding and heat resistance is very good. Costs are higher than average baked coatings. It has excellent non-wetting surface and repels the adherence of other materials. It has proved useful on rols, pans, molds, plates and heaters where sticking is a problem. Excellent releasing properties.

In general, the future for Kel-F looks very encouraging. Application methods will have to be improved slightly to reduce costs and raw material costs should also be reduced. From work now underway, it seems highly probable that both of these phases of cost will be reduced, thus creating a greater demand for its use and making it more available for general consumption.

ASA's New Stainless Standard Is Issued

Dimensions for Schedule 58 stainless steel pipe are now included in the newly revised edition of American Standard B36.19, Stainless Steel Pipe, offering opportunity for greater economy in the cost and use of the critical metal, according to the American Standards Association.

The three schedules of pipe thickness covered in the original edition of the Standard in 1949, Schedules 10S, 40S and 80S for sizes one-eighth inch through 12 inches are retained in the revised edition. Schedules 40S and 80S respectively have the same thickness as Standard Wall and Extra Strong Wall wrought steel pipe, covered by American Standard B36.10-1930 (now B36.10-1950). Schedule 10S pipe, the first new schedule of thickness to be standardized in over 15 years, is approximately one-half the weight of Schedule 40S. The new Schedule 5S pipe is approximately one-third lighter than Schedule 10S.

Behind the Scenes at **PLS...**

Where Ideas Come to Life for More Dependable Protection

Here is another of the unseen services that give you more for your money in pipe cleaning, priming, coating and wrapping at PLS. In this modern machine shop, specialists convert the ideas born in the engineering laboratory into original equipment to serve all six Pipe Line Service plants. These machine shop facilities make possible constant improvements in equipment and service that are reflected in the high quality protection provided for PLS customers.

21 Years of Dependable Service

PIPE LINE SERVICE PLS CORPORATION

Pioneers in Steel Pipe Protection
General Office and Plant: Franklin Park, Illinois

Plants at Glenwillard, Penna.; Longview, Texas; Corpus Christi, Texas; Harvey, Louisiana; and Sparrows Point, Maryland

NACE News

Chicago Meeting to Feature Educational Lectures

Philadelphia Section Schedules Discussion Session on October 10

Plans have already been made for the fall meeting of the Philadelphia Section to be held Friday, October 10 at the Poor Richard Club. A round table discussion has been scheduled. Howard H. Bennett, program chairman is urging all members to send in their questions for the round table discussion so questions may be sorted and classified in advance of the meeting.

The Philadelphia Section will also meet Friday, December 12, and Friday, February 13, 1953.

Tulsa Hears Verink Talk on Aluminum

The announcement of the appointment of a membership committee, an entertainment committee, a talk on the "Use of Aluminum in Petroleum Production and Processing," by Ellis D. Verink, Jr., of the Aluminum Co. of America, and a report on the Third Annual Short Course for Pipe Liners were high lights of the April meeting of the Tulsa Section.

Bob Nee was appointed chairman of the membership committee. As part of its duties, the membership committee will maintain a file of pocket name cards for use at each meeting. Red Lawlor was appointed chairman of the entertainment committee, with Hugh Brady and Ed Bartolina as members. The entertainment committee will decide on questions involving social periods, refreshments and like arrangements.

Following his talk on use of aluminum, Mr. Verink answered numerous questions concerning the specific applications of aluminum structures, vessels and tubing.

Bill Huddleston and Jim Cowles were awarded lapel pins for their contributions to making the Pipe Liner's Short Course a financial success.

Pipe Lines Fastest Growing System

The world's fastest growing transportation system is underground, according to Charles A. Scarlott, manager of technical information for Westinghouse Electric Corp., in his talk before the Heat Exchange Institute at Hershey, Pa., entitled "What's New in the Electrical Industry." In 1950, there were about 450,000 miles of pipe line, Mr. Scarlott said.

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The National Association of Corrosion Engineers now has more than 3200 members.

TP-15 Meeting Set For September 19

Next meeting of Technical Practices Committee 15—Corrosion Control in the Transportation Industry, is scheduled for September 19, 1952, Kenneth K. Kessler, committee chairman has announced.

Teche Section Meeting Is Attended by 40

Because of the low pressure sweet oil well corrosion problems existing in the vicinity, members of Teche Section were particularly interested in the talk, "How to Predict and Control Sweet Oil Well Corrosion," by H. L. Bilhartz of the Atlantic Refining Co., Dallas, Texas. A lively discussion and question period followed the talk which was delivered at the May meeting of the Section, held in New Iberia, La. About 40 were present.

To aid in the drive for new members, Russell W. Schutt, secretary of the Teche Section, has requested more membership blanks from the NACE Central Office.

Shreveport Section Has Annual Fish Fry

Shreveport Section held its annual Fish Fry June 20 at Lake Bistineaux, La. There were approximately 60 members and guests present to enjoy the fish and fishing. Among the visitors attending were T. F. P. Kelly and Warren McKenney of Houston, Texas.

LoPrete Elected Head Of N. Central Region

Jack H. LoPrete of Spray-Coat Engineers, Detroit, Mich., has been elected chairman of North Central Region. Other officers elected and certified after a tabulation by Eugene Huth and Edwin W. Vereeke, tellers, were: Norman A. Kerstein, Detroit Edison Co., Detroit, Mich. vice-chairman; James F. Hirshfeld, The Hinchman Corp., Detroit, secretary, and Leon D. Cook, Jr., Wyandotte Chemical Corp., North Plant, Wyandotte, Mich.

The newly elected officers take over at once.

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In December the NACE publishes in Corrosion a cross-indexed table listing all technical material printed during the year.

Eleven Symposia, Two Round Tables Also Projected

There will be three educational lectures on corrosion fundamentals during the March 16-20, 1953 Chicago Conference of the National Assocation of Corrosion Engineers. They will be held each afternoon Tuesday through Thursday. This novel feature has been added to the proposed eleven symposia and two round table discussions.

Each of the eleven symposia will include from four to five papers. The Tuesday morning technical session will end early so members may attend the annual association business meeting. While symposia chairmen have secured several papers for their symposia, it was pointed out by H. W. Schmidt, Technical Program chairman, presentation of technical papers, like attendance at the conference, is open to association members and non-members alike. A special request was made for information on papers from officers of NACE regions and sections and from members of the NACE Technical Practices Committee.

Persons who have papers they would like to present at the Chicago meeting are invited to communicate directly with the chairman of the appropriate symposium, or with either of the following: H. W. Schmidt, Materials Engineering Service, Building 1-177, The Dow Chemical Company, Midland, Mich., Technical Program Chairman, or with Frank L. Whitney, Jr., Monsanto Chemical Co., 1700 South Second St., St. Louis, Mo., co-chairman.

The symposia planned, with names of chairmen where appointed are:

Cathodic Protection—E. P. Doremus, Cathodic Protection Service, 4601 Stanford St., Houston, Texas, chairman.

Chemical Industry—C. A. Coberly, 316 Oak Manor Lane, Webster Groves, Mo., chairman.

Corrosion Principles—No chairman named.

Electrical and Communication Industry—C. H. Fellows, Detroit Edison Co., 2000 Second Ave., Detroit, Mich., chairman.

Fresh and Salt Water Corrosion—V. V. Kendall, National Tube Division, U. S. Steel Company, Box 266, Pittsburgh, Pa., chairman.

High Temperature Corrosion—J. J. B. Rutherford, Babcock & Wilcox Co., Tubular Products Division, Beaver Falls, Pa., chairman.

Oil and Gas Production Industry—H. L. Bilhartz, Atlantic Refining Company, Box 2819, Dallas, Texas, chairman.

Pipe Line Industry—No chairman named.

Protective Coatings—L. L. Whiteneck, Long Beach Harbor Dept., 1333 Embarcadero, Long Beach, Cal., chairman.

(Continued on Page 4)

Non-Metallic Materials San Francisco Topic

M. K. Weber of Shell Development Co. discussed the use of rigid non-metallic materials of construction for process industries at the June 11 dinner meeting of San Francisco Bay Area Section's meeting. There were present 46 members and guests.

Mr. Weber's talk also covered flexible sheet materials used as linings. He also covered wood, rubber, glass, asbestos phenolic compounds and impervious carbon as well as the newer polyvinyl chloride, fluor carbons, polyethylene and high strength glass plastic laminates.

T. J. Smith, Electric Steel Foundry, was named treasurer to fill the unexpired term of C. E. Haney who is leaving.

Four Correspondents Of Corrosion Changed

Four changes of correspondents of Corrosion magazine have been made. New correspondents are C. L. Bulow, Corrosion Metallurgist for Bridgeport Brass Company, Bridgeport, Conn., who will act in the non-ferrous metals field, and J. J. Halbig, of Armco Steel Corp., Middletown, Ohio, who will act in the ferrous metals field. They replace, respectively, B. B. Morton, with The International Nickel Co., New York City, and Arba H. Thomas, Armco Steel Corp., Middletown, Pa.

R. W. Flournoy, Corn Products Refining Co., Chemical Division, Argo, Ill., replaces Henry W. Foelsch, Stalpic Division, A. Gusmer, Inc., Woodbridge, N. J., as correspondent for the Pulp, Paper, Mining and Food industries. H. O. Saunders, Jr., American Telephone and Telegraph Co., New York, N. Y., replaces J. W. Danser, of the same company as correspondent for the Telephone, Telegraph and Radio industries.

These changes are the first under the policy adopted at the Galveston Conference by the Publication Committee whereby replacement of correspondents of Corrsion and of members of the editorial review committee will be made on a scheduled basis.

A BURIED TREASURE

FOR

CORROSION CONTROL...

WITH

Standard Magnesium Anodes

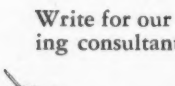
If you have a corrosion problem, Standard Magnesium Anodes can *truly* be a *"Buried Treasure"* of savings for you.

HERE'S HOW . . .

A good anode is like a good car battery . . . it gives you efficient, long-lasting service at a minimum cost. That is what Standard Magnesium anodes offer.

Certified Spectrographic Analysis records are furnished with all anodes shipped, insuring the user that he is receiving a product that will deliver maximum current efficiency.

Write for our free booklet on corrosion control and let our engineering consultants explain how we can serve you.



Standard Magnesium Corporation

TULSA, OKLAHOMA

Educational Lectures–

(Continued From Page 3)

Refinery Industry—R. S. Treseder, Shell Development Co., 4560 Horton St., Emeryville, Cal., chairman.

Educational Lectures—R. B. Hoxeng, U. S. Steel Co., 234 Atwood St., Pittsburgh, Pa., chairman.

Technical sessions are scheduled in the morning from 9 to 11:30 and in the afternoons from 2 to 4:15, Tuesday through Thursday. The Tuesday morning technical session will end at 11 to permit attendance at the general business meeting of the association.

Round table discussions will be held on pipe line and general corrosion problems. These discussion sessions have proved to be among the best attended events on the technical program at previous NACE Conferences. Chairman of the General Corrosion Problems Round Table is C. F. Pogacar, Atlantic Refining Co., 260 S. Broad St., Philadelphia, Pa., and L. E. Stout of the School of Engineering, Washington University, St. Louis, has been named co-chairman.

Membership of NACE in Canada Grows Rapidly

An inrrease of more than 40 percent in membership of NACE has been registered in Canada since February 15. The addition of 21 members brings membership of Canadians in the association to 72 up to the middle of July.

Discussion continues on the organization of local subdivisions among Canadian members and formal organized affiliation of a Canadian organization with the NACE.

Baldwin Reappointed

L. A. Baldwin has been reappointed chairman of the NACE Regional Management Committee.

Price of Corrosion to Subscribers Increased

The charge for Corrosion to subscribers will be increased effective October 1. The association's executive committee at a meeting in Chicago last month ordered increases in subscription prices to non-members as follows:

Regular Subscription, 12 issues, $9.00.

Subscriptions to libraries of recognized educational institutions, 12 issues, $4.00.

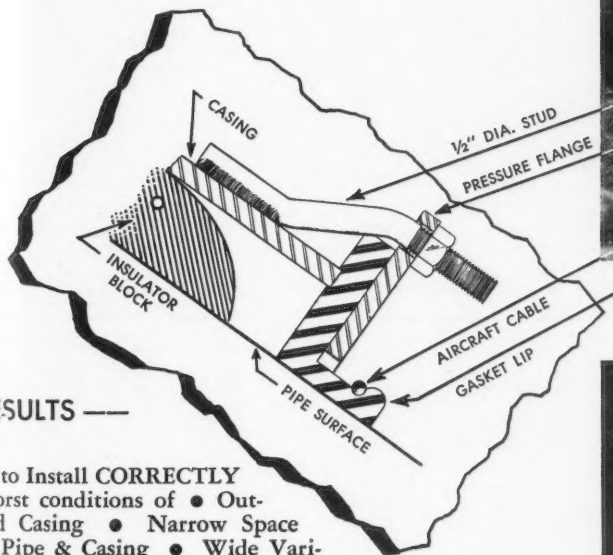
Price of single copies to all non-members of the association $1.

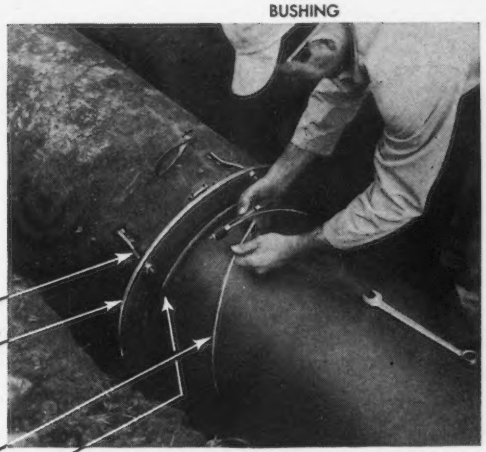
The price of single copies to members has not been increased and remains at 50c. These increases have no effect on the cost of Corrosion to association members.

PIPE-LINE TESTED, PROVED and ACCEPTED in '51

TYPE "L" WmSEAL CASING BUSHING*

A New Design: It BUTTS Against End of Casing Instead of Fitting Inside the Casing.

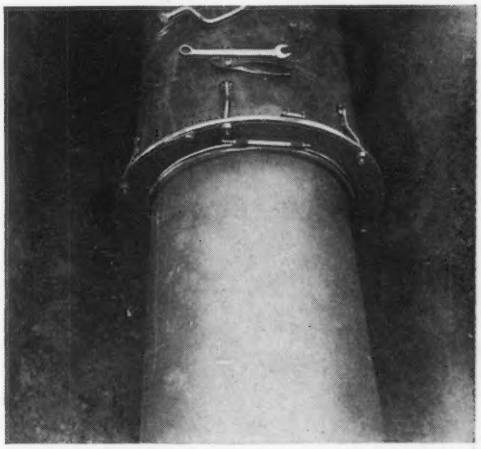




Assembling cable with rubber-covered union for clamping gasket lip to pipe.

RESULTS —

1. Easier to Install CORRECTLY under worst conditions of • Out-Of-Round Casing • Narrow Space Between Pipe & Casing • Wide Variations in Casing Wall and Coating Thickness • Mud • Casing ends beveled — by machine or hand torch.
2. WATER-TIGHT Seal with "L" gasket . . . . . .
   - BUTTED AGAINST CASING as pressure flange is tightened on ½" studs welded to casing.
   - TIGHT TO THE PIPE as aircraft cable (4,600# tensile) is tightened to gasket lip. Union is rubber covered to INSULATE galvanized cable assembly from bare casing structure.
3. Always Insulated from the pipe line when a Concentric-Support Insulator is installed just inside casing after the "drag section" is in place.



THE COMPLETED INSTALLATION
Note that galvanized cable and union are insulated from pressure flange and from pipe.

AS STRONG & DEPENDABLE AS THE MEN WHO INSTALL THEM

REPRESENTATIVES

Stuart Steel Protection Corp., Kenilworth, N. J. | H. E. Davis, Los Angeles 15, Calif. | James S. Kone Co., Amarillo, Texas | Keyes Tank Co., Provo, Utah | Keyes Tank & Supply Co., Casper, Wyoming | Canadian Equipment Sales & Service Co., Ltd., Edmonton, Calgary, Toronto, Canada

WRITE FOR BULLETIN 249A

T. D. Williamson, Inc.
TULSA 9, OKLAHOMA

8,000 Pipe Line Casings installed in 1951 with Williamson Bushings and Insulators.

Some 220 Attend Sea Horse Institute

Some 220 corrosion specialists invaded Wrightsville Beach June 4-6 to attend the informal conference known as the Sea Horse Institute. The conference included five technical sessions and inspection trips to the laboratory at Harbor Island and the atmospheric test lots at Kure Beach.

Among subjects discussed at the technical sessions were effect of cathodic protection on coatings, use of coating in condenser water boxes, coatings in general corrosion of heat exchanger tubes in polluted waters, experiences with cathodic protection of condenser boxes, corrosion of steel piling with emphasis on some West Coast piling for off-shore drilling rigs.

Great interest was shown in the new museum where test pieces were on display illustrating types of sea water attack on many types of metals and under many conditions. Specimens showing attack of numerous organisms on wood also were present.

The group attending the 1952 conference included specialists from 28 states and Canada, with New York, Pennsylvania, New Jersey, District of Columbia, Texas, Michigan, Connecticut and Ohio having ten or more representatives.

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CARL B. SMITH
Dearborn Chemical Company, Chicago, is exhibits chairman for the 1953 NACE Conference and Exhibition.

NBS Lists Articles Published in May 1952

The National Bureau of Standards has released the following list of articles published by the Bureau in May, 1952: "Solubility of carbon in 18-percent-chromium-10-percent-nickel austenite," 9 pp., 10 cents; "Synthesis and physical properties of n-heptane and 2,2,4-trimethylpentane," 6 pp., 10 cents; "Ionization constant of 5-5'-diethylbarbituric acid from 0° to 60°C," 8 pp., 10 cents; "X-ray protection design," 36 pp., 15 cents.

In the field of engineering: "Methods and equipment for testing printed-enamel felt-base floor covering," 10 pp., 15 cents; "Fire tests of gunite slabs and partitions," 11 pp., 15 cents; "Capacities of plumbing stacks in buildings," 28 pp., 20 cents.

In the field of mathematics: "On some functionals of Laplacian processes," 8 pp., 10 cents; "Uniformly best constant risk and minimax point estimates," 5 pp., 10 cents; "A note on bounds of multiple characteristic roots of a matrix," 2 pp., 5 cents; "On the estimation of an eigenvalue by an additive functional of a stochastic process with special reference to the Kac-Donsker method," 8 pp., 10 cents; "Some general theorems on iterants," 2 pp., 5 cents.

In the field of physics: "Mechanical properties of metals at low temperatures," 206 pp., $1.50; "Absolute viscosity of water at 20°C," 31 pp., 20 cents; "Sensitive mercury-level detecting unit for monometers," 5 pp., 10 cents. "Binding energies for electrons of different types," 7 pp., 10 cents; "Infrared absorption spectra of five halomethanes," 6 pp., 10 cents.

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The National Association of Corrosion Engineers now has more than 3200 members.

The 1952 Annual Directory of Membership was published in the March 1952 issue of Corrosion.

WOW!

The Gal would no doubt be welcome on a desert isle, back row of a movie, Saturday night square dance or any other civil (or un-civil) occasion. All Right, All Right, the Gal's name is Maude and her phone number is Webster 1941. Now, will you read the rest of this?

You'll admit she's pretty, but, have you seen one of our insulating bushings designed especially for gas meter service? How about letting us send you testing samples, the bushings that is, they'll speak for themselves. (Sure wish I had that Monkey's job!)

ALL TYPES OF INSULATION
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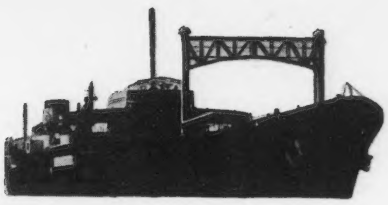
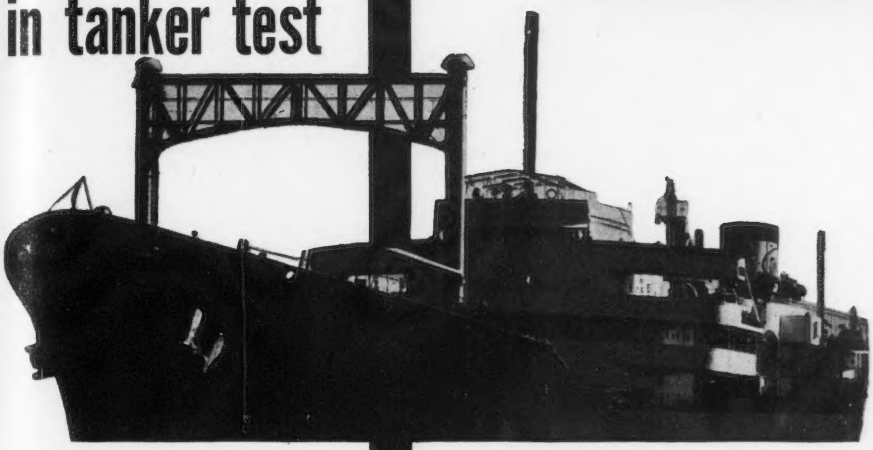
SERVICE ENGINEERS, INC.
Manufacturers of Industrial Plastic Products
3030 W. Pafford P. O. Box 11068 Fort Worth 9, Texas

SANTOLENE C proves effective in tanker test





Here are the results of a test, started several months ago, to prove the effectiveness of Santolene C in preventing corrosion in a tanker carrying light petroleum products:

How test was made: Strips in two cargo compartments in a tanker were sandblasted clean. Petroleum products carried in these compartments were treated with Santolene C at the rate of 12 lbs./1000 bbls. Two other compartments were cleaned for comparisons. Untreated petroleum products were carried in them. One treated and one untreated test compartment always made the return trip containing salt water ballast.

Here are results: After 8 months, the compartments were inspected. Sandblasted strips in tanks carrying Santolene C had slight, soft scale that could be removed by wiping. Areas not sandblasted had a dull, oily appearance. There was apparently no new scale on these areas and the scale present was clinging tightly to the sides. (This was scale that had been left on the metal when the test started.)

A hard rust-red scale had formed on the sandblasted areas of the compartments without Santolene C. Large sheets of this scale were falling from the sides.

During the period of the test, 153,000 pounds of scale was removed from all compartments of the ship. Scale removed from the two tanks in which Santolene C treated products were carried was 50% to 60% less than that removed from the untreated compartments of the ship.

Santolene C also has proved its effectiveness in actual service by major oil companies. If you have a corrosion problem with transportation or storage of light petroleum products, investigate Monsanto Santolene C. For complete information, write MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second Street, St. Louis 4, Mo. *Santolene: Reg. U. S. Pat. Off.*

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University College
Washington University ....., 1952
St. Louis 5, Mo.

Enclosed find check (money order) in the amount of ten dollars made payable to Washington University as deposit on tuition for the Short Course on Corrosion scheduled for the week of September 8.

Name .....

Position and Company.....

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Address .....

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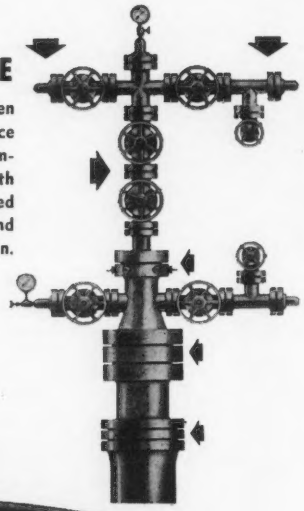
CORROSION STRIKES HERE

Corrosion in the ring is certain to result when dissimilar metals are flanged up in the presence of a low resistance liquid or electrolyte. Machining of cloth-reinforced plastics exposes the cloth to liquids which hasten deterioration. Forged steel ring gaskets cannot stop this corrosion and alloys frequently increase the rate of corrosion. But it *can* be eliminated!



STOP CORROSION WITH

PESCO

PLASTIC RING SEAL GASKETS

PESCO Gaskets are *molded* of Fiberglas and a special resin, and provide *positive protection* against the flow of electric current between dissimilar metals in a joint. They are form fitting under pressure, have high mechanical strength, and are unaffected chemically by any of the gases or fluids encountered in oil and natural gas production or transmission. When used with insulated sleeves and washers around the bolts, PESCO Gaskets will electrically insulate any joint, and will eliminate corrosion caused by galvanic, long line or stray electric currents. Thousands in service on high pressure christmas trees over the past five years. Widely used to insulate well structures against currents flowing from pipe line systems. Investigate PESCO Plastic Ring Seal Gaskets today . . . sizes available to replace metal rings built to API specification 5-G-3. Prices on request.

PLASTIC ENGINEERING AND SALES CORP.

P. O. BOX 1037 FORT WORTH, TEXAS

Five-Day Washington University Short Course Scheduled September 8-12

Registration at the Washington University, St. Louis, Short Course on Corrosion has been limited to 100. The course, to be given September 8-12, in cooperation with the National Association of Corrosion Engineers will cover major corrosion engineering areas with leading engineers as lecturers.

Tuition for the five-day course will be: For NACE members, $40; for others, $47.50. Of the non-members' fee $7.50 is allocated as a membership fee for the calendar year 1953 if an application for membership is filed and accepted.

The course schedule calls for morning sessions daily from 9 to 12 and afternoon sessions daily from 2 to 5. The sessions will consist of lectures and discussion period alternately.

Technical Program

Monday, Sept. 3—Corrosion Reactions, Factors and Fundamental Mechanisms, H. H. Uhlig, Massachusetts Institute of Technology, Cambridge.
Treatment of the Environment—Chemical Methods, Selection and Behavior, Norman Hackerman, University of Texas, Austin.

Tuesday, Sept. 9—Guides to Proper Selection of Materials of Construction for Particular Environments, W. Z. Friend, The International Nickel Co., Inc., New York.
Types of Corrosion—Diagnosis and Treatment of Corrosion Difficulties, M. G. Fontana, Ohio State University, Columbus.

Wednesday, Sept. 10—Corrosion Testing Procedures and Evaluation Factors to be Considered in Laboratory and Field Studies. F. L. LaQue. The International Nickel Co., Inc., New York.
Designing to Prevent Corrosion—Basic Principles and Standards of Equipment Design, Installation and Maintenance, R. B. Mears, United States Steel Co., Pittsburgh.

Thursday, Sept. 11—Cathodic Protection—Theory and Measurement, J. M. Pearson, Sun Oil Co., New Town Square, Pa.
Cathodic Protection—Practical Application and Economics, A. W. Peabody, Ebasco Services, Inc., New York.

Friday—Protective Coatings (Metal and Organic)—Fundamentals and Selection, K. G. Compton, Bell Telephone Laboratories, Murray Hill, N. J.
Protective Coatings—Surface Preparation, Application and Behavior, A. J. Liebman, Dravo Corp., Pittsburgh.

Registrations Accepted

Registrations will be accepted at once, and must be accompanied by a deposit of $10.

Housing will be available in men's dormitories, cafeteria meals will be provided and off-hour entertainment features will be suggested.

•

In December the association provides in Corrosion a cross-indexed table listing all technical material printed during the year.

•

Corrosion magazine publishes information on activities involving corrosion from trade and technical groups all over the world.

Sulphurous soil was MURDER on pipes... till plastic tape stopped the killer!

In less than two years, corrosion from sulphates caused complete failure of buried pipe in Palo Alto, California. Ordinary coatings couldn't stand up under the punishment.

Now service "T's" and fittings are wrapped with "Scotch" Plastic Electrical Tape. The problem's solved for good.

What makes this tape so tough? Vinyl plastic in the backing resists acids, oils, alkalies, water and common commercial solvents. And this tape never dries out.

Applicators prefer it, too! It's easier, faster to apply—neater when the job's done.

Try "Scotch" Plastic Electrical Tape yourself. It's available in three thicknesses, many widths and lengths. Order a supply today!

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SCOTCH BRAND
ELECTRICAL TAPES

The term "Scotch" and the plaid design are registered trademarks for the more than 200 pressure-sensitive adhesive tapes made in U.S.A. by Minnesota Mining & Mfg. Co., St. Paul 6, Minn.—also makers of "Scotch" Sound Recording Tape, "Underseal" Rubberized Coating, "Scotchlite" Reflective Sheeting, "Safety-Walk" Non-slip Surfacing, "3M" Abrasives, "3M" Adhesives. General Export: 122 E. 42nd St., New York 17, N. Y. In Canada: London, Ont., Can.

Corrosion Scientist Heads Lubrication Engineers' Society

A corrosion scientist, W. E. Campbell, is among the national officers elected at the annual meeting of the American Society of Lubrication Engineers. Mr. Campbell was elected vice-president-at-large. Elected president was M. E. Merchant. W. H. Fowler, Jr. was selected as secretary-treasurer and W. P. Youngclaus, Jr. was named administrative-secretary.

Mr. Campbell is the author of papers on results of fundamental studies in corrosion and boundary lubrication. For three years during World War II he guided research on corrosion problems for the Manhattan District Project.

Mr. Campbell did his graduate work at Columbia university. Since 1926 he has been a member of the research department, Bell Telephone Laboratories. He was a member of the sub-committee on Friction Lubrication and Wear, National Advisory Committee for Aeronautics, is active in committee work for the ASTM, ACS and AAAS, and has been a member of the Special Research Committee on Lubrication of the American Society of Mechanical Engineers for 20 years.

Mr. Merchant, the new president, formerly was regional vice-president. He has been associated with the research department of the Cincinnati Milling Machine Co. since 1941 and is author of numerous papers on metal cutting, friction and lubrication. He is co-author with Hans Ernst of the chapter on Principles of Metal Cutting and Machinability in the Tool Engineers' Handbook.

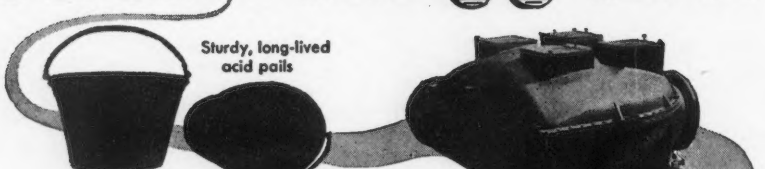
He is a graduate of the University of Vermont and holds a D.S. degree for graduate work at the University of Cincinnati.

Mr. Fowler has an extensive background in the design, construction and servicing of heavy machinery in all parts of the world. He was responsible for development of the solid injection Diesel which opened the way for application of this type of prime mover to automotive and locomotive use. During World War I he was connected with the Emergency Fleet Corporation Division of the U. S. Navy. In 1930 he became associated with the Pure Oil Co. In World War II he served on a Navy Trial Board and was a member of the ODT Committee in Chicago.

Mr. Youngclaus joined Stewart Warner Corp. after World War II. During the war he was in charge of Dodge-Chicago Aircraft Engine Plant. Previously he was a "rough neck" in the Oklahoma oil fields, foreman in a gypsum plant in Texas and a sales engineer for the Pennzoil Co. He is a mechanical engineering graduate of Northwestern University and is a member of the ASME.

New regional vice presidents of the American Society of Lubrication are: H. E. Mahncke, J. W. Hopkinson, A. S. Horwitz; and T. A. Marshall. Former president, C. E. Schmitz is new chairman of the presidential council. Directors are A. E. Baker, Jr., John Boyd, P. F. Chappell, Wilbur Deutsch, George Findlay, D. D. Fuller, N. H. Schell and A. O. Willey.

For More Than 50 Years...



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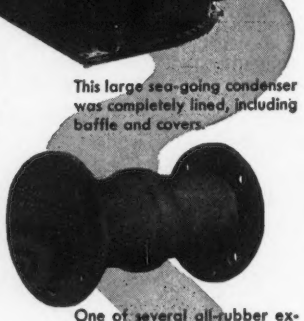
The La Favorite method, developed over the years, has consistently proved its merit as a primary source of corrosion protection. Inspection of equipment in use for many years after lining and/or covering has disclosed that the La Favorite method of application and compounding of the rubber stock have always been equal to the life of the rubber.



This large sea-going condenser was completely lined, including baffle and covers.

One of several all-rubber expansion joints for the power plant of a public utility.

For details on lining or covering of processing lines and equipment, send blue prints for estimate of cost, or write for bulletins on your type of equipment.

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Pittsburgh Diffraction Conference Scheduled

The Tenth Annual Pittsburgh Diffraction Conference will be held at Mellon Institute of Industrial Research, Pittsburgh, Pa., Nov. 6-7, 1952. Technical sessions are being arranged on "Instrumentation and Methods," and "Neutron Diffraction and General Diffraction Studies."

Contributed papers on these and related subjects will be considered in the order in which they are received. Titles should be submitted to the program chairman, R. K. Scott, Hall Laboratories Inc., Box 1346, Pittsburgh 30, Pa. before Sept. 1, 1952.

This year's conference will include a symposium of invited papers in the field of "Order—Disorder Studies." Further information and a copy of the preliminary program when available may be obtained by writing E. E. Wicker, U. S. Steel Co., Research and Development Laboratory, 234 Atwood St., Pittsburgh 13, Pa.

Instrument Clinic Set

The Seventh National Instrument Conference and Exhibit, to be held in Cleveland, Ohio, Sept. 8-12, 1952 will be preceded by a preconference Instrument Society of America instrument maintenance clinic.

The clinic, the fourth one to be held, will cover thermal elements, electrical measuring circuits, pressure elements and primary flow elements, electrical deflection and indicators, total quantity meters, electronics positioning devices, pneumatic positioning devices and final control elements.

Dormitory, cafeteria and classroom facilities will be available on the campus of Case Institute of Technology. Dormitory rates are $3.00 per night for single rooms, $2.00 a night for double. Meals will be served in Tomlinson Hall, next to the dormitory. Meals will cost about $4.00 a day. Applications for advanced registration should be sent to P. V. Jones, manager, Instrument Society of America, Pittsburgh 33, Pa.

Milan Laboratory

A brief history of the laboratory of Politecnico di Milano, and short illustrated descriptions of the activities and equipment of the laboratory are given in a recent Italian publication. The laboratory is used for research in the fields of electrochemistry, physical chemistry and metallurgy. One of the photos shows the corrosion laboratory and equipment. Title of the publication is, "Il laboratorio di Elettrochimica, Chimica Fisica e Metallurgia del Politecnico di Milano."

Corrosion Control of Steel Docks Is Topic At Corpus Christi

Ray Pfrehm, of Humble Pipe Line Company addressed eleven members and five guests of Corpus Christi Section at a June 25 meeting on the subject "Corrosion Control of Steel Docks."

The meeting was the final one for the summer. Next meeting scheduled is the section's annual barbecue in September.

JACKSON SQUARE—Laid out in 1720, this famous New Orleans landmark was first known as the Place d'Armes. Facing the square is the St. Louis Cathedral, which is flanked left and right by the Cabildo and Presbytere; the upper and lower Pontalba apartment buildings face each other across the square.

Exceptional Technical Program and Intriguing Entertainment to Feature New Orleans Meeting

Arrangements Made For Interesting Stay In Crescent City

The Entertainment Committee for the October 1-3 meeting of South Central Region at New Orleans believes the colorful old city offers so much in the way of recreation that the principal duty of the committee will be to provide information. Lloyd Sevin, of Louisiana Power and Light Co., chairman of the committee, said plans are directed to high lighting the entertainment features of the city rather than providing something to do during off-hours.

The Jung Hotel, headquarters for the meeting, is located conveniently to downtown New Orleans shopping district, the French Quarter, and quick public transportation anywhere in the city. The hotel has been redecorated recently, and ample facilities for committee meetings and technical sessions have been provided.

Following the preliminary technical session and registration Wednesday, October 1, an informal "get re-acquainted" party is scheduled at the Jung to serve as a starter for an evening of relaxation in the city according to the individual wishes of the registrants.

On Thursday, the usual annual business luncheon will be held immediately following the morning technical session. At this meeting, a financial report will be given and other business of the region discussed.

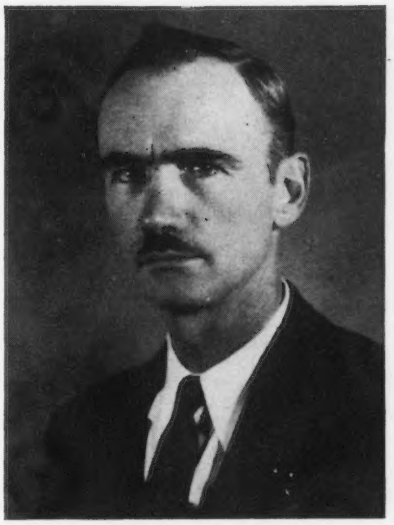
The annual Fellowship Hour and Banquet will be held at the Jung Hotel Friday evening concluding the meeting. Entertainment during this event will be furnished by the selected best from local singing and dancing teams and an excellent orchestra. Excellent food will be served.

•

NACE will publish an annual directory of committee members including all organized committees of the association.

•

The 1952 Annual Directory of Membership was published in the March, 1952 issue of Corrosion.



JOHN E. LOEFFLER

Thornhill-Craver Co., Houston, Technical Program Chairman for the South Central Region's 1952 meeting at New Orleans.

Two Women Participate In New Orleans Meeting

Two outstanding women workers on corrosion will participate in the New Orleans meeting of the NACE South Central Region in October. They are Mrs. M. L. Lytle of Humble Oil and Refining Co., Houston, co-author with J. A. Caldwell of the same firm of the paper "Bacterial Corrosion of Offshore Structures." Ivy M. Parker, with Plantation Pipe Line Co., Bremen, Ga., will present a report titled "Progress of Some of the Research in Corrosion Problems of Large Diameter Product Pipe Lines." Besides being editor of the NACE monthly magazine Corrosion, Dr. Parker is active in other technical organizations in the petroleum field.

Emphasis Is Placed On Gulf Coast's Corrosion Problems

Design against corrosion and engineering approaches to the solution of corrosion problems will be the principal themes of the technical program of the South Central Region's meeting at New Orleans October 1-3. An outline calling for the presentation of 17 papers, in four symposia has been prepared by John E. Loeffler, of Thornhill-Craver Company, Houston, technical program chairman. Some other details of the meeting have been announced tentatively also.

Two unusual features have been proposed for the program and both are well under way to complete organization. One is the presentation of a Technical Practices Committee Report by a subdivision of TP-1 on Corrosion of Oil and Gas Well Equipment. The other will consist of four discussions of corrosion work done by other petroleum industry associations and the relation of the work of these other groups to similar work in the NACE. These presentations are expected to attract wide interest.

Committee Work to Be Seen

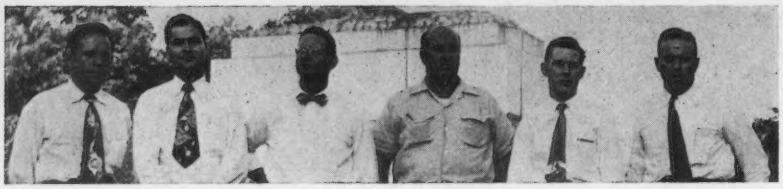
The manner in which the NACE technical practices committees function will be shown through the presentation of a report by Technical Practices Committee 1-H on Corrosion of Oil String Casing. Jack H. Battle, of Humble Oil and Refining Co., Houston, chairman of this committee, will preside.

Registrants at the conference will witness the committee in action from seats arranged in auditorium style.

The second of the features is expected to clarify the differences between the NACE's corrosion work and that of other organizations. Continuous liaison is necessary if the corrosion activities of various organizations are not to be repetitive, the association believes.

The areas covered by the smyposia are those selected in a canvass of in-

(Continued on Page 12)



IN CHARGE OF ARRANGEMENTS AT NEW ORLEANS—Some of the NACE members in charge of arrangements for the 1952 South Central Region meeting at New Orleans are, left to right, Henry Allen, Allen Cathodic Protection Co., Harvey, La., Registration; Cliff Barr, Shell Oil Co., New Orleans, General Arrangements; Lloyd Sevin, Louisiana Power & Light Co., New Orleans, Entertainment; Howard Dick, Products Research Service, Inc., Westwego, La., Local Arrangements; Jack Martin, The Texas Co., Production Dept., New Orleans, Publicity, and Phil Wogan, Products Research Service, Inc., Printing. Not shown but also active in the preparations for the meeting are Oscar Langhans, inspection and field trips; F. S. Bird, The California Co., New Orleans, transportation; Wesley B. Root, projection; A. F. Blumer, solicitations.

Emphasis Placed on Gulf Coast Problems

(Continued From Page 11)

terests of South Central Region's membership made by Mr. Loeffler in 1951. The subject matter is keyed to the petroleum and petrochemical industries, to the pipe line transportation field and to the marine exposure field. These subjects were those in which most interest was expressed in the canvass.

All activities will be at the Jung Hotel.

Four Symposia Projected

The program projected, officials and the titles of papers and names of authors arranged so far are:

Wednesday, October 1

2:00 p.m. Tulane Room. Report of TP-1H on Corrosion of Oil String Casing. Jack L. Battle, Humble Oil and Refining Co., Houston, chairman, presiding.

Thursday, October 2

9:00 to 11:45 a.m. Tulane Room. Oil and Gas Industry Symposium. Edward C. Greco, Production Dept., United Gas Company, Shreveport, chairman; D. F. Dial, Production Department, Pure Oil Co., Houston, co-chairman; aides, D. A. Shock, Continental Oil Co., Ponca City, Okla. and Robert C. Booth, Shell Oil Co., Houston.

Mill Scale on Steel and Its Effect on Steel Corrosion in Salt Water, by T. P. May and R. B. Teel, The International Nickel Co., Inc., New York.

Bacterial Corrosion of Offshore Structures, by J. A. Caldwell and Mrs. M. L. Lytle of Humble Oil and Refining Co., Houston.

Review: Use of Sodium Chromates and Alkalis for Controlling Corrosion in Gas Condensate Wells, by Kenneth C. Eilerts, Dept. of Interior, Bureau of Mines, Bartlesville, Okla.

2:30 to 4:45 p.m. Processing Plant Symposium. Sam Muery, Freeport Sulphur Co., Port Sulphur, La., chairman; Ray Cherry, Monsanto Chemical Co., Texas City, Texas, co-chairman; aide, Clyde C. Loyd, Esso Standard Oil Co., Baton Rouge, La.; Alan Whitehead, Metal Goods Corp., New Orleans.

Oil Refinery Corrosion Problems, by W. A. Trusty, Chief Chemist, Arkansas Fuel Oil Company, Shreveport, La.

Plastic Materials of Construction, by K. B. Seymour, Atlas Mineral Products Co., Mertztown, Pa.

Designing to Prevent Corrosion, by F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.

Statistics, a Useful Tool for Examination of Corrosion Data, by C. F. Lewis, Plant Metallurgist, Cook Heat Treating Co., Houston.

The Corrosion Engineer Uses Plastics, by Frank L. Whitney, Jr., Monsanto Chemical Co., St. Louis.

Friday, October 3

9:00 to 11:45 a.m. Oil and Gas Transportation Symposium. K. D. Wahlquist, Southern Union Gas Co., Dallas, chairman; F. E. Pyeatt, Jr., Mid-Continent Pipe Line Co., Tulsa, co-chairman; aides, J. A. Holloway, Houston Pipe Line Co., Edna, Texas; Sidney Trouard Jr., New Orleans Public Service, Inc., New Orleans.

Pipe Line Coatings, by F. W. Fair, Jr., Koppers Co., Pittsburgh.

A New Development in Magnesium Anodes for Pipe Line Cathodic Protection by R. C. Jorgerson and Burke Douglas, Dow Chemical Co., Freeport, Texas.

Cathodic Protection of Uncoated Pipe Lines, by Joe F. Tatum, Willmut Gas and Oil Co., Hattiesburg, Miss.

The Tank Ship and Its Corrosion Problems, by J. D. Sudbury and D. A. Shock, Continental Oil Co., Ponca City, Okla.

Cathodic Protection of Under River Pipe Lines, by C. C. Loyd, Esso Standard Oil Co., Baton Rouge, La.

2:00 to 4:45 p.m. Oil and Gas Transportation Management and Economics Symposium. Earl W. Unruh, Sinclair Pipe Line Co., Independence, Kans., chairman.

Review of Some of the Work of a Typical API Pipe Line Sub-Committee on External Corrosion Protection of Crude Oil Pipe Lines and Its Relation to Similar Work in NACE, by L. F. Scherer, Assistant General Manager, Texas Pipe Line Co., Houston.

Review of Some of the Work of a Typical API Pipe Line Sub-Committee on Internal Corrosion Protection of Crude Oil Pipe Lines and Its Relation to Similar Work in NACE, by Russell A. Brannan, Humble Pipe Line Company, Houston.

Review of Some of the Work of a Typical AGA Sub-Committee on Pipe Line Corrosion and Its Relation to Similar Work in NACE, by A. D. Simpson, Chief Engineer, Texas Division, United Gas Co., Houston.

Review of Corrosion Topics Studied by the Petroleum Industry Electrical Association's Corrosion Committee and Its Relation to Similar Studies by NACE, by A. L. Stegner, Corrosion and Communication Engineer, Tennessee Gas Transmission Co., Houston.

Two Papers of Special Interest to Shipyards And Steel Fabricators

Shipyards and fabricators of steel serving the oil industry on the Gulf Coast will find valuable data in two of the technical papers to be presented at the October 1-3 meeting of South Central Region, National Association of Corrosion Engineers at New Orleans. One paper deals with corrosion problems in oil tank ships and the other with the effect of mill scale on the corrosion of steel in sea water. Both are by recognized experts on the subjects.

"The Oil Tank Ship and Its Corrosion Problems," by J. D. Sudbury and D. A. Shock of the Development and Research Dept. of Continental Oil Co., Ponca City, Okla., will be given during the Friday morning technical session at the Jung Hotel. Both authors have had long experience with corrosion problems in connection with the handling of petroleum.

T. P. May and R. B. Teel, both with The International Nickel Company's Corrosion Engineering Section, will present a paper Thursday morning on "Mill Scale on Steel and Its Effect on Steel Corrosion in Sea Water." This paper will be based on the extensive tests conducted by The International Nickel Company's Harbor Island and Kure Beach testing stations. The International Nickel Company has collected a vast quantity of material on the corrosion of steel in salt water and the authors are expected to draw liberally on it for their material.

Petroleum Field Gets Emphasis in Program

Technical papers related to corrosion in the petroleum field predominate in the technical program for the South Central Region's 1952 meeting. Fourteen technical papers or discussions are directed to the oil and gas industries. The subject matter covers everything from large diameter pipe lines to bacterial corrosion of offshore structures. The program thereby reflects the principal activity of members of the NACE South Central Region—petroleum and its by-products.

Subject matter of the remainder of the papers on the program is of interest to engineers in the oil business. It can be said the whole program is directed to interest the oil man, with special emphasis on transportation and production.

Technical Program Chairman John E. Loeffler has been told that all but one or two of the papers or discussions will be prepared for publication in the NACE journal Corrosion. Furthermore, for the first time at a South Central Region meeting, an effort will be made to collect discussions for publication with the technical papers.

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Plans have been made to mail to NACE members in South Central and South East Regions copies of an advanced program for the New Orleans meeting. Members and others elsewhere who wish copies may get them on request to Central Office NACE, 1061 M & M Building, Houston 2, Texas.

Ladies' Entertainment Program Is Readied

New Orleans' famous Vieux Carre, with its Old World atmosphere of ancient buildings, secluded courtyards, and dusty shops crammed with unknown treasures from bygone years beckons women accompanying their menfolk to the South Central Region's October meeting. The entertainment committee has arranged also for Thursday, October 2, a luncheon, style show and guided tour of the French Quarter. Besides, womenfolk will want to attend the Wednesday "get re-acquainted" party at the Jung, and the annual Fellowship Hour and Banquet Friday.

The Jung Hotel is located on Canal Street, convenient to the French Quarter and to other historical and interesting spots. The famous New Orleans riverfront can be reached quickly from the hotel's front door and the city's beautiful parks are readily available by public transportation.

Many interesting restaurants, where delicious food is served, shows, historical buildings and other places are sure to attract the attention of feminine and masculine visitors alike.

TP Report Session Will Be Featured

A unique feature of the technical program for the South Central Region's New Orleans meeting in October is the presentation of a technical committee report, with registrants as spectators. The region's officials felt many members who do not fully understand how the NACE technical committees function would welcome the opportunity to witness the presentation of a report of TP-1H on Corrosion of Oil String Casing.

The committee meeting, with Jack L. Battle, Humble Oil and Refining Co., Houston, presiding, will be held so registrants may witness the full proceedings. In this way it is hoped more NACE members will be brought to take interest in and participate in the activities of the technical committees.

Relationship Among Corrosion Inquiries Will Be Surveyed

The relationship between work done by other associations active in corrosion prevention in the petroleum field and that being done by the National Association of Corrosion Engineers will be the topic of the Oil and Gas Transportation Management and Economics Symposium at the South Central Region's 1952 meeting. Top echelon management and engineering officials will present the talks.

The four talks will cover the relationship between American Petroleum Institute's, American Gas Association's, and Petroleum Industry Electrical Association's work on internal and external corrosion of pipe lines and similar work being done by groups in the National Association of Corrosion Engineers. Speakers will be L. F. Scherer, Texas Pipe Line Co.; Russell A. Brannon, Humble Pipe Line Co.; A. D. Simpson, United Gas Co., and A. L. Stegner, Tennessee Gas Transmission Co.

OFFICIALS OF OIL AND GAS TRANSPORTATION SYMPOSIUM—Pictured above are the officials of the Oil and Gas Transportation Symposium to be given Friday morning, October 3 during the 1952 meeting at New Orleans of South Central Region NACE: K. D. Wahlquist, Southern Union Gas Co., Dallas, chairman; F. E. Pyeatt, Jr., Mid-Continent Pipe Line Co., Tulsa, co-chairman; aides: J. A. Holloway, Houston Pipe Line Co., Edna, Texas, and Sidney Trouard, Jr., New Orleans Public Service, Inc.

OIL AND GAS PRODUCTION SYMPOSIUM OFFICIALS—Officials in charge of the Oil and Gas Production Symposium to be held at New Orleans during the October 1-3 South Central Region 1952 meeting are (left to right): Edward C. Greco, Production Department, United Gas Co., Shreveport, chairman; D. F. Dial, Production Dept., Pure Oil Co., Houston, co-chairman; D. A. Shock, Development and Research Dept., Continental Oil Co., Ponca City, Okla. and Robert C. Booth, Corrosion Engineering Dept., Shell Oil Co., Houston, aides.

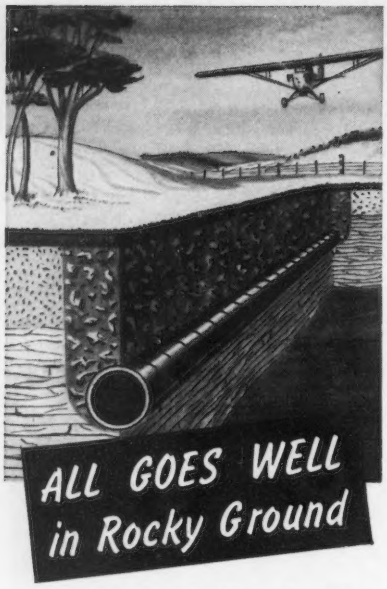
PROCESSING PLANT SYMPOSIUM OFFICIALS—Officials in charge of the Processing Plant Symposium at New Orleans Oct. 1-3 are as follows (left to right): Sam Muery, Freeport Sulphur Company, Port Sulphur, La., chairman; Ray Cherry, Inspection Dept., Monsanto Chemical Co., Texas City, Texas, co-chairman; Clyde C. Loyd, Inspection Dept., Esso Standard Oil Co., Baton Rouge, La., and Allen Whitehead, Metal Goods Corp., New Orleans, aides.

Two Papers Will Tell Merits of Plastics

Two papers on the use of plastics to combat corrosion in chemical process plants will be given at the South Central Region's New Orleans meeting in October. "Plastic Materials of Construction" is the title of a paper by K. B. Seymour of Atlas Mineral Products Co., Mertztown, Pa., and Frank L. Whitney of Monsanto Chemical Co., St. Louis, will speak on "The Corrosion Engineer Uses Plastics."

These papers are expected to provide useful practical information for engineers concerned with the application of plastic materials. In the same general sphere of interest is the paper by F. A. Prange of Phillips Petroleum Co., Bartlesville, Okla., titled "Designing to Prevent Corrosion."

MEZZANINE LOUNGE NO. 2, JUNG HOTEL —An example of the kind of accommodations available for registrants attending South Central Region's 1952 Meeting at New Orleans Oct. 1-3. This is a mezzanine at the Jung, headquarters hotel.

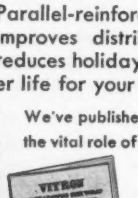


Pressure penetration of pipeline coatings cut one-half by VITRON Underground Pipe Wrap

How can you engineer so your pipeline patrol plane will consistently report "All Goes Well"—even in rocky ground? We ran a large number of tests to get the answer; that VITRON Underground Pipe Wrap reduces pressure penetration by about one-half. Rocks that would completely rupture plain coatings would make a small, harmless dent in coatings reinforced with VITRON Pipe Wrap.

Parallel-reinforced VITRON Wrap improves distribution of coating, reduces holidays, and means longer life for your pipe coating.

We've published the whole story of the vital role of VITRON Wrap in a new booklet, and would like you to have a copy. A call or a letter will bring a copy to you right away.



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UNDERGROUND PIPE WRAP

New Development in Magnesium Anodes to Be Revealed by Dow

Considerable interest has developed over the content of the paper "A New Development in Magnesium Anodes for Pipe Line Cathodic Protection," which will be presented by J. C. Jorgerson and Burke Douglas of Dow Chemical Co., Freeport, Texas, at the South Central Region's New Orleans meeting. The contents of this paper are a closely guarded secret and speculation is that the Dow company has made a significant discovery that will be helpful in protecting pipe lines.

The paper is scheduled to be presented during the morning of October 4 in the Oil and Gas Transportation Symposium.

MIT Dedicates New Metals Laboratory

Massachusetts Institute of Technology last month dedicated its new $1,000,000 metals processing laboratory. The laboratory, jointly administered by the departments of metallurgy and mechanical engineering, was made possible by a gift from the Alfred P. Sloan Foundation, Inc. which has given $8,500,000 to MIT.

The laboratory was created as an inter-departmental laboratory, "to bring the application of both metallurgical science and of engineering design to the basic crafts of machining, finishing, casting, forging, welding and related techniques of modern manufacturing."

One of the speakers, Dr. C. Richard Soderberg, head of the department of mechanical engineering said advances in other scientific fields have created new demands for materials which can withstand extreme conditions of temperature, corrosive atmospheres, radiation and stress.

Competition Opened For Foreign Research

National competition for posts in foreign lands conducting advanced research and in university lecturing are announced in a poster published by the Conference Board of Associated Research Councils, Committee on International Exchange of Persons.

Included for the competition are awards for Austria, Belgium and Luxembourg, Denmark, Egypt, France, Greece, Iraq, Italy, Netherlands, Norway, Turkey, the United Kingdom and Colonial Dependencies. Also included are awards for Japan, Pakistan, and the Union of South Africa.

The closing date for making application to participate in the competition is October 15, 1952. Booklets with detailed information may be obtained by writing the Committee at 2101 Constitution Ave., N. W., Washington 25, D. C.

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Corrosion magazine publishes information on activities involving corrosion from trade and technical groups all over the world.

CORROSION MEETINGS

1952

Sept.
4-6—AIChE (Regional Meeting) Chicago, Ill.
8-12—Instrument Society of America. Cleveland, Ohio.
10-13—Committee of Electrochemical Thermodynamics and Kinetics. Cambridge University, England.

Nov.
6-7—Tenth Annual Pittsburgh Diffraction Conference. Mellon Institute, Pittsburgh.

Dec.
7-10—AIChE, Annual Meeting. Cleveland, Ohio.

1953

Mar.
2-6—ASTM Spring Meeting and Committee Week, Detroit, Mich.

April
20-22—Metal Powder Association. Cleveland, Ohio.

June
29-July 2—ASTM Annual Meeting. Atlantic City, N. J.

Sept.
21-25—Instrument Society of America. Chicago, Ill.

Standards Price List Is Available Now

The American Standards Association has published a price list of approximately 2500 publications containing specifications and standard qualities for materials and articles used in almost every kind of manufacture or construction.

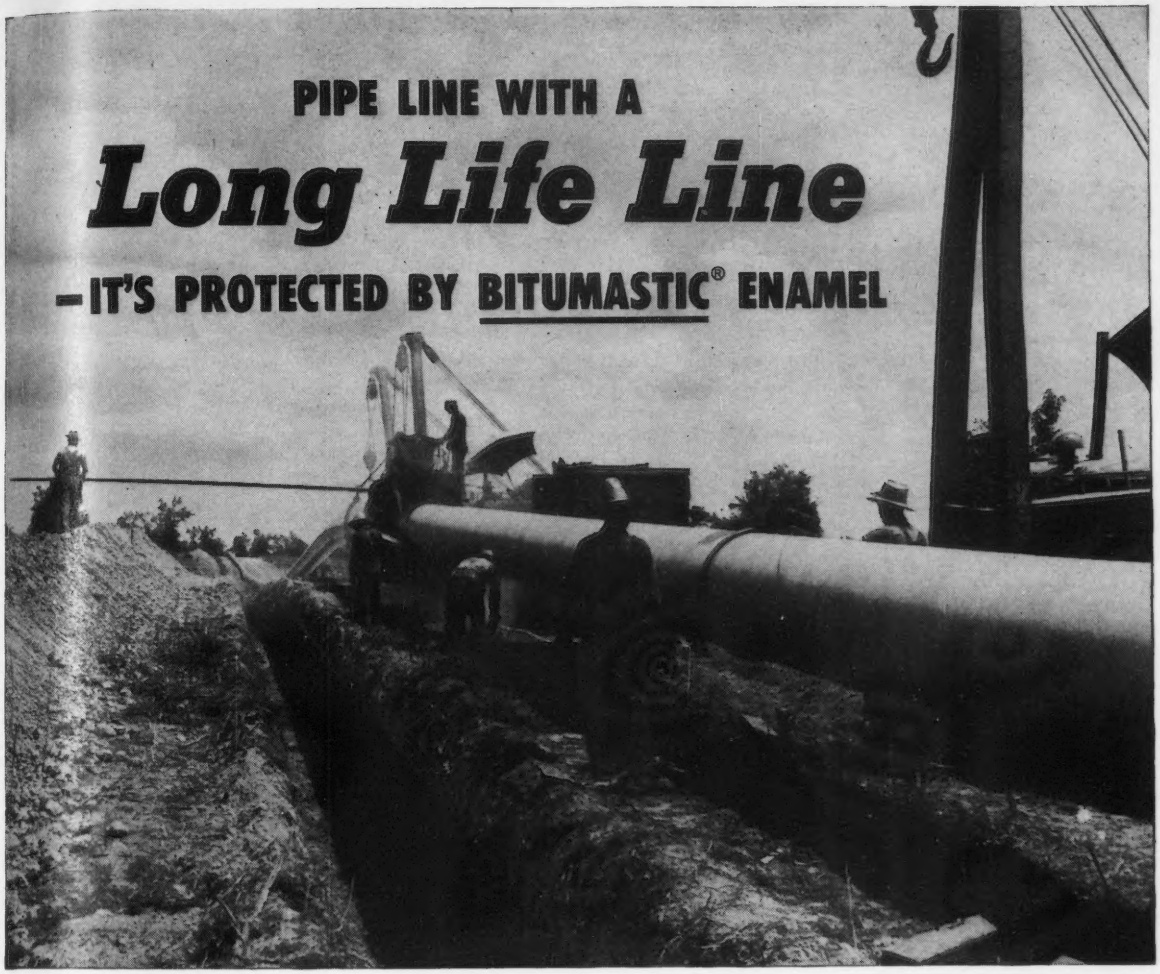
The American Standards Association, Inc. is the American clearinghouse for standards activity in the United States. It is a federation of more than 100 trade associations, technical societies, professional groups and consumer organizations. Some 2300 companies are affiliated with the ASA as company members. The ASA also represents American Business as the American member of the 33-nation International Organization for Standardization (ISO).

The separately bound price list is Part 2 of the June, 1952 issue of the magazine "Standardization." Single copies of "Standardization" are 35 cents. The address is 70 East 45th St., New York 17, N. Y.

NACE will pay 50c a copy for copies of MARCH CORROSION

subscribers or members find they do not need. The supply of this issue has been exhausted by the heavy influx of new association members and more copies are needed to supply others joining who want all 1952 issues.

- ***Mail copies to A. B. Campbell, National Association of Corrosion Engineers, 1061 M & M Building, Houston, Texas.***



This pipe line was coated with Bitumastic Enamel—then wrapped.

HERE's a steel pipe line that's almost completed. And once in service, this line will *stay* in service because it's protected by Bitumastic Enamel against severe corrosive conditions.

Bitumastic Enamels give pipe lines the best possible protection against all kinds of corrosion. Here's one reason: through the years these coal-tar enamels *keep* moisture away from pipeline surfaces, thus preventing corrosion. Two more reasons: these durable enamels don't disintegrate with age; they are chemically resistant to soil elements.

Because of Bitumastic Enamels, many oil and gas pipe lines laid 20 and 30 years ago are still giving good service today. Specify Bitumastic Enamels for your next pipe-line project, and give it the same effective protection. Your Koppers representative will give you complete details and estimates.

Bitumastic Enamels now available from Koppers new Fontana, California, Plant!

Koppers can now supply Bitumastic Enamels from its new plant at Fontana, California. This plant was built in order to give you better service in the west.

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INNER WOOD LINING
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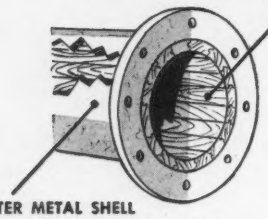

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wall thicknesses 5/64" to 1/4"

Ideal for corrosive liquids and gases including process waters, industrial waste liquors, acid, alkali and salt solutions, chemical gases, pulps and slurries. For catalog and additional information, write Dept. C

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Pure Aluminum Electroplated at Room Temperature from Organic Bath

A PRACTICAL PROCESS for electrodepositing aluminum at room temperature has recently been developed by D. C. Couch and Abner Brenner of the National Bureau of Standards. Dense, ductile deposits of the metal are being obtained at the bureau from a new type of organic plating bath[1] consisting of an ether solution of aluminum chloride and a metal hydride. The new bath is expected to find important application for electroforming articles with close inside tolerances, such as waveguides and for providing various types of equipment with a thin protective coating of aluminum.

Because aluminum is so far above hydrogen in the electromotive series of the elements, it has never been deposited from aqueous solutions, which always contain some hydrogen in ionized form. Aluminum is usually produced commercially from a bath of fused cryolite and aluminum oxide. However, this process must be carried out at a high temperature and the metal is obtained in a fused state, unsuitable for electroplating or electroforming. Electrodeposition from nonaqueous solutions has been tried in the past with some success but the procedure was too difficult for practical applications and the deposits were lacking in purity, ductility and other desirable qualities.

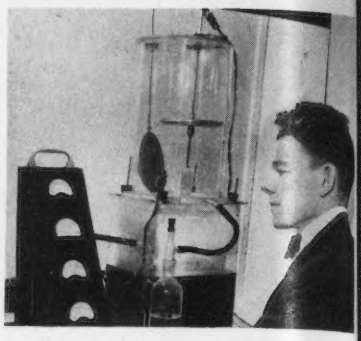

Figure 1—Organic plating bath recently developed by the National Bureau of Standards for electrodepositing aluminum at room temperature. To avoid the introduction of moisture, the bath is covered with a closed container through which dry air is passed before the plating operation begins. After the container has been flushed out, the lid of the plating vessel is lifted by the rod at left, and the cathode is lowered into the bath by the central rod, which also carries a lid for the vessel. Aluminum rods entering the plating vessel through rubber stoppers serve as anodes. The bottle in the foreground contains sulfuric acid used as a drying agent.

Plating Other Metals Explored

The National Bureau of Standards is now conducting extensive research in an effort to develop methods for depositing in good physical form unusual metals such as molybdenum, tungsten, titanium and zirconium. Both fused salts and baths of organic solvents are being investigated. One of the first metals studied was aluminum. The success of the aluminum plating bath, developed in the course of this work, may be expected to give added impetus to the current widespread efforts to obtain other metals in pure form from nonaqueous solutions.

The aluminum plating bath is prepared at NBS by adding either lithium hydride or lithium aluminum hydride to an ethyl ether solution of anhydrous aluminum chloride. For best results the ether should be anhydrous and alcohol-free. The concentration of the aluminum chloride is not critical and may vary from 1 to 4 molar. Current densities may be as high as 4 or 5 amperes per square decimeter. However, if thick deposits are desired, the current density should not be greater than 2 amp/dm.[2] Because of the high concentration of aluminum chloride in the ether, the bath is not as flammable as would normally be expected.

Moisture Is Excluded

To prevent the entrance of moisture, the bath is prepared and used in a closed container consisting of a glass plating vessel with a tightly fixed polyethylene lid. Anodes of aluminum rod pass through the lid, and the objects to be plated (cathodes) are introduced and removed through a central hole which is ordinarily kept closed with a rubber stopper. If hermetically sealed, the bath will keep for several weeks; however, under ordinary operating conditions the solution slowly deteriorates and eventually gives streaked and brittle deposits.

No agitation of the bath is necessary. In fact, a quiescent bath is actually an

(Continued on Page 18)

It takes patience, precision, and the highest degree of human skill to change, with a few light taps, a relatively worthless stone to a priceless gem. In the diamond cutting industry, fortunes rest on the *human equation.*

On the human equation, too, rests the efficiency of your cathodic protection system. Efficient corrosion control not only requires the use of the best equipment available, but depends on an exacting analysis of *your* problem, and design, installation and testing by top-notch specialists in the field.

Hundreds of operating installations attest to the dependability and skill of the ERP engineer. Highly trained, and backed by years of experience, he can help you solve *your* pipe corrosion problems too. E-20.1

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OVER 15 YEARS OF CATHODIC PROTECTION ENGINEERING, RESEARCH AND DEVELOPMENT

NEW from Johns-Manville TRANTEX *polyvinyl* TAPE

. . . a cold applied wrap that protects underground and overhead oil and gas lines from corrosion

TRANTEX® TAPE simplifies coating of welded joints of mill-wrapped pipe—shields the pipe against corroding agents.

This pipeline needed protection without disrupting service. TRANTEX TAPE did the job. *No heated kettles required . . . labor costs kept low.*

FOR more than fifty years Johns-Manville has been manufacturing pipeline protection material. This experience, plus the knowledge gained in the research laboratory and in the field about the effects of corrosion, have gone into the making of "Trantex"—a new plastic tape for extending the service life of oil and gas lines.

Trantex needs no special equipment in its application. It is easily applied by hand or hand-operated devices. A pressure-sensitive adhesive forms a tight bond with the pipe—shields it against the general corrosive conditions that cause most pipeline failures. Trantex has proved remarkably resistant to the effects of soil chemicals, acids, alkalies, alcohols, oil and grease, sunlight and aging.

Check the basic properties of Trantex in the table below—each one is extremely important in the control of corrosion.

For more detailed information about Trantex *polyvinyl* Tape, write to Johns-Manville, Box 60, New York 16, N. Y.; in Canada, 199 Bay Street, Toronto 1, Ont.

	*V-10	**V-20
Dielectric Strength	10,000 V	20,000 V
Insulation Resistance	100,000 megohms	100,000 megohms
Operating Temperature	200 F	200 F
Adhesion	30 oz per inch	20 oz per inch
Tensile Strength	30 lbs per inch	56 lbs per inch
Elongation at Break	250%	300%

"Trantex" is a black polyvinyl tape. It is available in two thicknesses—*V-10 is a 10 mil tape for general conditions, and **V-20 is a 20 mil thickness for use where a more rugged coating is specified.

JM JOHNS-MANVILLE PRODUCTS

Johns-Manville TRANTEX® *polyvinyl* TAPE

PROTECTS PIPELINES AGAINST CORROSION

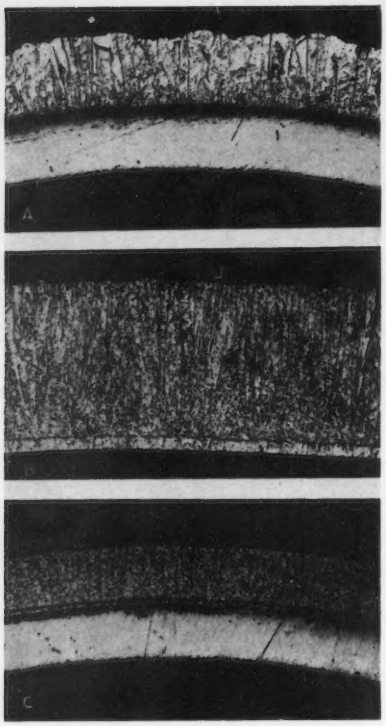

Figure 2—Photomicrographs of aluminum deposits obtained with the new organic plating bath developed by the National Bureau of Standards. Deposits obtained at lower current densities (A) are characterized by large, columnar crystals. Use of periodic reverse current produces some grain refinement (B). Addition of β,β'-dichloroethyl ether to the bath results in a very fine grain structure (C). The ductility and hardness of the deposits vary considerably. Deposit A is quite ductile while C is very brittle. The hardness of deposit A is 37 Vickers; of B, 67 Vickers; and C, 97 Vickers. (X 67 approx.)

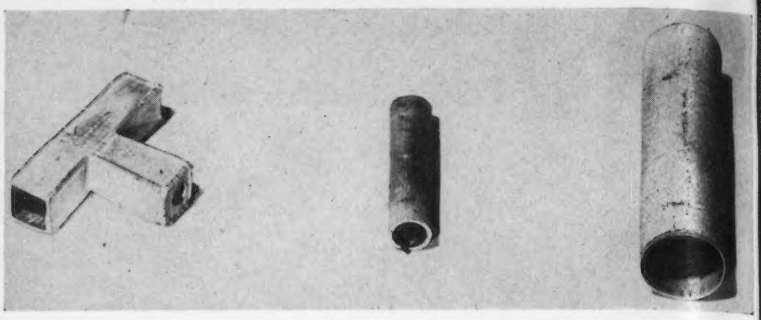

Figure 3—Objects electroformed of aluminum by means of the new hydride plating bath developed by the National Bureau of Standards. The aluminum was deposited on copper, which was then dissolved out with nitric acid, leaving the aluminum replica.

Pure Aluminum—

(Continued From Page 16)

advantage as the sediment from the anodes settles to the bottom of the vessel, making bagging of the anodes and filtration of the solution unnecessary. The composition of the bath is easily controlled since the only constituent that changes appreciably in concentration during the plating process is the lithium hydride. Occasional additions of lithium hydride increase the life of the bath, but in time the lithium hydride becomes insoluble and the bath can no longer be used.

When sufficient lithium hydride is used, the deposits are white, mat and quite ductile; but if the lithium hydride content is too low (less than 3 or 4 g/1), the deposits become hard, brittle and grey. Still further reduction of the hydride content produces deposits that are dark and stressed and that often crack or peel from the cathode. Ordinarily deposits 0.01 inch or more thick are visibly crystalline, but this effect can be reduced somewhat by adding a small amount of β,β'-dichloroethyl ether. Pitting, which frequently occurs in aqueous baths, is practically nonexistent in the ether bath.

Cathode and anode efficiencies for the process are approximately 100 percent. Deposits 0.05 inch thick have been prepared at the bureau, and thicker deposits should be possible if the sharp edges of the cathode are shielded to prevent treeing.

[1]For further details, see "A hydride Bath for the Electrodeposition of Aluminum" by Dwight E. Couch and Abner Brenner *J. Electrochem. Soc.*, **99**, 234 (1952), June.

List of Speakers on Corrosion Available

For use of secretaries of NACE and of other members who may have use for it, Central Office has compiled a list entitled "Prospective Speakers for Addressing Meetings." The list was compiled in response to numerous requests from program chairmen for names of persons qualified and able to address meetings of the association.

Copies of the list have been mailed to chairmen of NACE Regions and Sections. Other interested members of the association may get copies by writing Central Office NACE, 1061 M & M Building, Houston 2, Texas.

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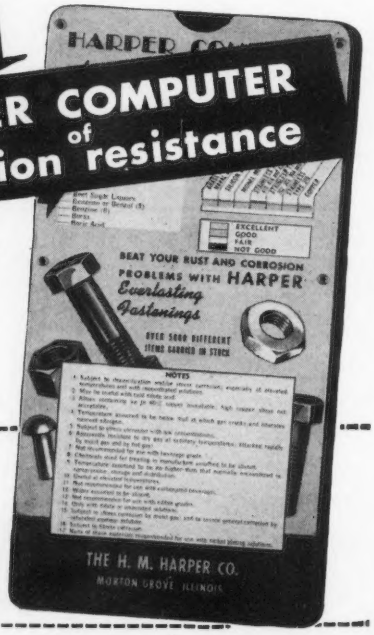

Gives you a quick, easy method of determining what metal alloys to use in connection with 143 different corrosive agents. Ideal for metallurgists, product designers, engineers, chemists, purchasing agents. Sized to fit your pocket. Developed by The H. M. Harper Co., America's leading specialist in non-ferrous and stainless fastenings.

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Positions Wanted

Corrosion Engineer, graduate, 5½ years' pipe line experience. Cathodic protection bare and coated pipe lines plus coating inspection. Want change involving minimum of traveling. CORROSION, Box 52-7.

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Leading engineering and construction firm offers staff positions to corrosion engineers with minimum of three or four years' experience in corrosion investigations and design of cathodic protection on pipe lines and lead cables in country and city networks. Must be graduate electrical engineer (or equivalent). Work involves extensive travel, with headquarters in New York City. Salary commensurate with experience and ability. Good opportunity for advancement. Write CORROSION, Box 52-8.

How Would You "COOL OFF" Boiling Hydrochloric Acid?

THIS CONDENSER...STILL GOOD AFTER 2½ YEARS SERVICE ...PROVIDES AN ANSWER

Where processing equipment is exposed to strong corrosives, trouble and expense may often be eliminated by use of a high nickel alloy.

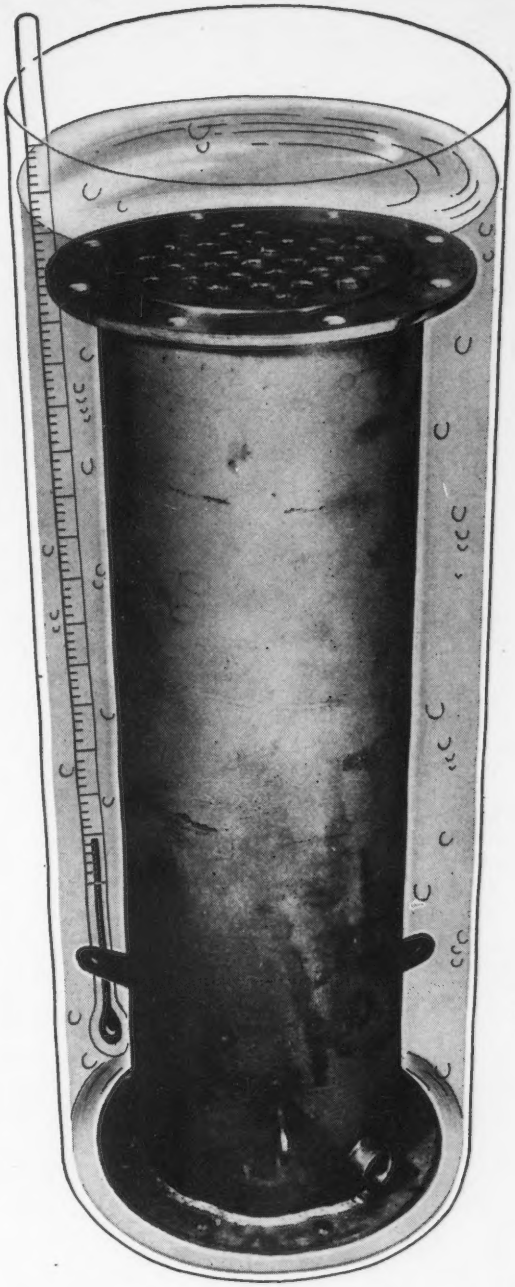
For instance, a series of nickel-base alloys trade-named "Hastelloy," produced by the Haynes Stellite Company, Kokomo, Indiana, a Division of Union Carbide and Carbon Corporation, are widely used for components exposed to corrosion from sulfuric and hydrochloric acids.

Hastelloy alloy B . . . selected for tubes and end plates of the condenser shown above . . . has given more than 2½ years of service in hydrochloric acid distillation, 2 to 3 days per week, 8 hours per day, yet shows no visible deterioration.

The fabricator, Kay Industries of Detroit, chose this high nickel alloy because it is one of the very few commercially available materials adequate to handle acid in concentrations that vary from 1 to 10%, with temperatures up to the boiling point . . . making it one of the most corrosive agents known to the chemical industry.

Hastelloy alloy or some other high nickel alloy may be the complete answer to your particular equipment or production problems. Write us, today, for counsel and data.

At present, most of the nickel produced is being diverted to defense. Through application to the appropriate authorities, nickel is obtainable for the production of engineering alloys for many end uses in defense and defense supporting industries.



COMPONENTS OF HIGH NICKEL ALLOY WITHSTAND BOILING ACIDS. Condenser tubes ½" in diameter, welded from 16-gauge Hastelloy alloy B, and end disks of the same material, ⅜" thick by 7" diameter, are still good after 2½ years exposure to one of the chemical industry's most corrosive agents . . . boiling hydrochloric acid.

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NACE

New Members and Changes of Address

- This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

NEW MEMBERS

(Changes Through June 27, 1952)

ALABAMA

KATTUS, J. ROBERT, Southern Research Inst., 917 South 20th St., Birmingham 5, Alabama.

CALIFORNIA

ASHLINE, ROBERT R., 410 Ducommun St., Los Angeles 12, Cal.
BARBER, HARRY, Norman S. Wright & Co., 2779 Folsom, San Francisco 11, Cal.
BENAWA, JACK E., Solar Aircraft Co., 2200 Pacific Highway, San Diego 12, Cal.
BRADBURY, FRED D., Kettleman North Dome Assoc., Bin "C", Avenal, Cal.
COFFY, JOSEPH W., The Republic Supply Co. of California, 2600 S. Eastland Ave., Los Angeles, Cal.
CROWHURST, FRANK C., Chemical Process Co., 901 Spring St., Redwood City, Cal.
DOWNING, DALE F., Div. of Highways, Bridge Dept., State of Cal., P. O. Box 1499, Sacramento, Cal.
DE LEW, E. RICHARD, Yosemite Chemical Co., 1040 Mariposa St., San Francisco 7, Cal.
EFFINGER, R. T., Shell Oil Company, Martinez Refinery, Martinez, Cal.
FISHER, RALPH L., Rhodes Lewis Co., 6151 W 98th, Los Angeles 45, Cal.
FRISIUS, EDWARD N., Magna Products, Inc., P. O. Box FF, Santa Fe Springs, Cal.
JACOBS, EUGENE F., Specialty Resin Company, 2801 Lynwood Road, Lynwood, Cal.
JONES, HARRY L., James Lithgow Co., Inc., 4663 East Sheila St., Los Angeles 22, Cal.
JURSCH, CHARLES F., Southern Pacific Co., 65 Market, San Francisco, Cal.
LESTER, LOUIS B., Rectifier Engineering Co., Inc., 1803 E. 7th St., Los Angeles 21, Cal.
LOCKHART, FRANK J., 1900 Strand, Hermosa Beach, Cal.
LOPER, D. ROGER, Standard Oil Company of California, 225 Bush St., San Francisco, Cal.
MINTZ, BERNARD, Hughes Aircraft Company, Florence & Teale Sts., Culver City, Cal.
NELSON, RALEIGH P., National Pipe Coatings, Inc., 3480 East Raldolph St., Huntington Park, Cal.
ORR, ARTHUR C., Procter & Gamble Mfg. Co., 1601 W. 7th St., Long Beach 2, Cal.
OSTLING, WILLIAM S., Signal Oil and Gas Co., 811 W. 7th St., Los Angeles 17, Cal.
PANI, LEONARD S., Industrial Engineers, Inc., 817 East 59th St., Los Angeles 1, Cal.
PEROW, ROBERT H., Johns-Manville Products Corp., P. O. Box 9067, Long Beach 10, Cal.
SCOTT, GORDON N., Richfield Bldg., 555 So. Flower St., Los Angeles 17, Cal.
SHAFFER, JAMES A., JR., Schlage Lock Company, P. O. Box 3324, San Francisco 19, Cal.
VOORHEIS, WILLIAM H., American Potash & Chemical Corp., Box 1395, Trona, Cal.
WAHLEN, FRANK B., Coachella Valley County, Water District, Coachella, Cal.
WEINER, MILTON, Rheem Manufacturing Co., 12000 E. Washington Blvd., Whittier, Cal.
WELSH, J. V., Owens Fiberglas Corp., 3445 W. 8th, Los Angeles 5, Cal.
ZEH, HENRY P., Standard Oil Co. of California, Richmond, Cal.
ZEILBERGER, ERNEST J., North American Aviation, Dept. 95, Group 4, Lakewood Blvd., Downey, Cal.

DELAWARE

DEWSON, THOMAS E., Gates Engineering Company, P. O. Box 1711, Wilmington, Del.

DISTRICT OF COLUMBIA

HARMON, RICHARD E., Gates Engineering Co., 1500 Massachusetts Ave., N. W., Washington 5, D. C.
HIGGINS, R. I., United Kingdom Scientific Mission, 1800 K Street, N. W., Washington, D. C.
McAMIS, JAMES W., JR., Washington Gas Light Co., 1100 H Street, N. W., Washington 1, D. C.

FLORIDA

BOSTWICK, THOMAS W., City of Jacksonville, Utilities Bldg., 34 South Laura St., Jacksonville, Florida.
ZUMSTEIN, L. P., Eriez Manufacturing Co., Fort Orange, Florida.

GEORGIA

PECK, E. J., JR., Amercoat Corporation, 122 Candler Bldg., Atlanta, Ga.

ILLINOIS

CYBA, HENRY A., Witco Chemical Co., 6200 W. 51st St., Chicago, Ill.
HESS, WILLIAM L., Anesite Company, 3575 Touhy Ave. (P. O. Chicago 45), Lincolnwood, Ill.
KALHAUGE, VIGGO M., Standard Oil Co. (Ind.), 910 South Michigan Ave., Chicago, Illinois.
ROBIN, JOSEPH F., Johns-Manville Sales Corp., Merchandise Mart Plaza, Chicago 54, Illinois.
SCHULZE, ROBERT E., Culligan Zeolite Co., Northbrook, Ill.
THELEN, FLOYD E., Scaife Company, 1611 First National Bank Bldg., Chicago 3, Ill.
WATERS, ROBERT G., Aluminum Company of America, 520 North Michigan Ave., Chicago 11, Ill.

INDIANA

HOXIE, EARLE C., R. R. No. 1, Hillsdale, Indiana.

KANSAS

MILTNER, DONALD E., Socony Vacuum Oil Co., Inc., Central Pipe Lines Div., P. O. Box 1882, Wichita, Kan.

LOUISIANA

ELKINS, JOE G., Sun Oil Company, P. O. Box 549, Opelousas, La.
WINTERS, ROBERT K., The Atlantic Refining Co., 203 No. College St., Lafayette, La.

MASSACHUSETTS

MILLER, HARVEY S., New England Hardfacing Co., 678 Brookline Ave., Brookline, Mass.

MISSISSIPPI

McILHENNY, G. N., G. N. McIlhenny and Associates, P. O. Box 248, Lake, Miss.

NEW JERSEY

MUELLER, MAX F., J. T. Baker Chemical Co., Phillipsburg, New Jersey.
POWERS, JOHN B., Linde Air Products Company, 686 Frelinghuyzen Ave., Newark, New Jersey.

NEW YORK

DAVIS, RUSSELL L., California-Texas Oil Co., 551 5th Ave., New York, New York.

(Continued on Page 22)

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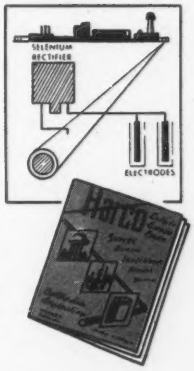

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(Continued From Page 20)

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JOECKS, ADOLPH K., Consolidated Edison Co. of N. Y., Inc., 708 First Avenue, New York, New York.
OTTO, WALTER W., Otto Bros. Maintenance Co., 99-12 Metropolitan Avenue, Forest Hills 75, New York.
PRESTON, ALBERT L., American District Steam Co., Bryant St., North Tonawanda, New York.

OHIO

BATES, ROBERT L., International Engineering, Inc., 1145 Bolander Ave., Dayton 1, Ohio.
BOMBERGER, HOWARD B., JR., 623 Minerva St., E. Liverpool, Ohio.
DYE, THOMAS O., Owens-Corning Fiberglas Corp., Nicholas Bldg., Toledo 1, Ohio.
GAMBOW, LEWIS J., Pioneer Alloy Products Co., 16601 Euclid Ave., Cleveland, Ohio.
ROEHL, EDWARD J., Thomas Strip Div., Pittsburgh Steel Co., Delaware Ave., N. W., Warren, Ohio.
VAUGHAN, LEWIS H., Babcock-Wilcox Res. & Dev., Harrisburg & Sawburg Roads, Alliance, Ohio.

OKLAHOMA

EVERETT, O. W., Oklahoma Natural Gas Co., 624 So. Boston, Tulsa, Okla.
LAFORTUNE, ROBERT J., Reilly Tar & Chemical Corp., P. O. Box 7031, Tulsa, Okla.
McDERMOTT, BYRON, Southwestern Bell Telephone Co., 1101 Telephone Bldg., Oklahoma City, Okla.
MONTGOMERY, BEN C., Owens-Corning Fiberglas Corp., 222-224 Mayo Bldg., Tulsa, Okla.
NICHOLS, AUGUSTO BARRIENTOS, University of Oklahoma, Norman, Okla.

PENNSYLVANIA

EACHES, ALBERT R., Philadelphia Electric Co., 1008 Walnut St., Philadelphia, Pa.
LITTLE, HARRY J., R. D. No. 2, Kennett Square, Pa.
PELLEGRINO, FRANK M., Allied Chem. & Dye Corp., Barrett Div., Margaret & Bermuda Sts., Frankford, Philadelphia 37, Pa.
RISLEY, ROGER E., 335 Interstate Parkway, Bradford, Pa.

TEXAS

BOND, BETHEL, Cathodic Protection Service, 4601 Stanford, Houston, Texas.
CRIBLEY, K. C., Stratton Pipe Line Corp., Box 1702, Corpus Christi, Texas.
LANCON, ALBERT A., Eastern States Petroleum, Box 5008, Houston, Texas.
LEMCKE, EWAID E., Hydrocarbon Construction Company, 656 M & M Building, Houston 2, Texas.
McGREGOR, JAMES, McGregor Brothers, Inc., P. O. Box 301, Odessa, Texas.
SCHOLL, RUSSELL C., Corrosion Control Co., P. O. Box 18263, Houston 23, Texas.
STEINHAUFF, FREDERICK P., Humble Oil & Refining Company, P. O. Box 2180, Houston, Texas.

WEST VIRGINIA

GARLETTE, WILLIAM A., JR., Monsanto Chemical Company, Nitro, West Va.

Foreign

CALLANDER, W. M., c/o Trinidad Leaseholds, Ltd., Pointe-A-Pierre, Trinidad, B. W. I.
DAINO, PIETRO, Socony Vacuum Italiana, Casella Postale 269, Naples, Italy.
DEWAR, JOHN S., National Carbon Ltd., 805 Davenport Rd., Toronto 4, Ontario, Canada.
FERRER, JUAN GOMEZ, J. Gomez Ferrer Co., 51 Tapia and McCleary Sts., Santurce, Puerto Rico.
GRANDI, DR. ING. ALBERTO, Societe Nazionale Metanodotti, Corso Venezia 16, Milano, Italy.
HEWES, FRANK W., Canadian Protective Coating, Ltd., 9336-91 St. Edmonton, Alberta, Canada.
HOPKINS, ARTHUR JAMES, Hume Steel Ltd., P. O. Box 4534, Melbourne, C. I., Vic., Australia.
KILLAM, F. RICHARD, Industrial Coatings Ltd., 1920 Main St., Vancouver, B. C.
KOZAK, STEPHEN, Canada Wire & Cable Co. Ltd., Postal Sation R, Toronto 17, Canada.
LEVELTON, BRUCE H., B. C. Research Council, University of B. C., Vancouver 8, B. C.
MAW, J. T., Corrosion Eng., Andian National Corporation, Cartagena, Colombia, S. A.
MOYLE, M. W., Cia Carbonifera de Sabinas, S. A. Rosita, Coahuila, Mexico.
PATTERSON, DAVID W. E., Dominion Natural Gas Co., Ltd., 315 Colborne, Brantford, Ontario, Canada.
PERKINS, GEORGE M., Creole Petroleum Corp., Apartado 889, Caracas, Venezuela, S. A.
PETRUSCHKA, MAX, M. E., Engineering Office, P. O. Box 1377, Jerusalem, Israel.
SHERMAN, CARL L., Phillips Electrical Works, Ltd., Brockville, Ontario, Canada.
SIEBERT, H. E., Kendall Company (Canada) Ltd., Curity Ave., Toronto, Ontario, Canada.
THOMPSON, HARVEY W., 350 Dufferin Avenue, Apt. 102, London, Ontario, Canada.

CHANGES OF ADDRESS

(Old Address Follows New in Parenthesis)

ALABAMA

CHRISTIAN, CLARENCE R., 704 Randolph St., Huntsville, Ala. (Guided Missile Dev. Gr., T & E Div., Redstone, Arsenal)

ARKANSAS

SHAW, A. G., Ebasco Services, Inc., P. O. Box 176, North Little Rock, Ark. (P. O. Box 2899, Little Rock)

CALIFORNIA

DOTY, ROBERT O., 261 East Fir Avenue, Oxnard, Cal. (U. S. Naval Air Missile Test Center, Point Mugu, Cal.)

COLORADO

LOOS, DE LASSO, General Delivery, Durango, Colorado (1500 N. Big Spring, Midland, Texas)

DISTRICT OF COLUMBIA

KEMP, JAMES T., American Brass Company, 1511 K St., N. W., Washington 5, D. C. (4522 Lowell St., N. W., Washington 15, D. C.)

ILLINOIS

PERKINS, WENDELL L., 24 Jefferson Ave., Elgin, Ill. (411 Marion Drive, Longview, Texas)
PHILLIPS, WILLIAM D., Chicago Decorating Company, 1845 West Carroll Avenue, Chicago 12, Ill. (516 N. Sangamon Street)

KENTUCKY

JONES, WALTER F., Mid-Valley Pipeline Company, Box 433, Clarkson, Ky. (Bramlette Building, Longview, Texas)

LOUISIANA

ALLEN, HENRY W., Allen Cathodic Protection Company, P. O. Box 386, Harvey, La. (149 Metairie Lawn Drive, New Orleans 20, La.)
ALLEN, W. O., United Gas Pipe Line Co., P. O. Box 1407, Shreveport, La. (P. O. Box 780, Wichita Falls, Texas)
LOYD, CLYDE C., Route 1, Baker, La. (4565 Sherwood Drive, Baton Rouge 5, La.)
McMILLAN, W. A., JR., 703 Cleveland St., Lake Charles, La. (412 Ethyl St.)
MORRIS, J. M., United Gas Pipe Line Co., P. O. Box 1422, Monroe, La. (P. O. Box 780, Wichita Falls, Texas)
PARNELL, H. S., United Gas Pipe Line Company, P. O. Box 1407, Shreveport, La. (P. O. Box 1020, Jackson 5, Miss.)
SULLIVAN, M. N., Rosson-Richards Co., P. O. Box 66, Harvey, La. (1090 M & M Bldg., Houston 2, Texas)

MICHIGAN

HASKINS, FRANK D., c/o Library, General Motors Institute, Flint 2, Mich. (3rd & Chevrolet Avenues)

MARYLAND

MAYER, WILLIAM J., A. M. Byers Company, 7 St. Paul St., Baltimore 2, Md. (10 E. Lexington Street)
SHINNAMON, CHARLES W., 1806 Everest St., Silver Spring, Md. (Washington Gas Light Co., 1100 H St., N. W., Washington 1, D. C.)

MISSISSIPPI

LOVELL, ODUS W., JR., United Gas Pipe Line Company, 240 Bon Air, Jackson, Miss. (P. O. Box 86, Petal, Miss.)

NEW JERSEY

FOELSCH, HENRY W., 34 Kate Lane, Metuchen, New Jersey (1802 W. Byron St., Chicago 13, Ill.)
MILLER, M. C., Box 66, Route No. 2, Allendale, New Jersey (1142 Emerson Ave., W. Englewood, New Jersey)
PRIOR, JOSEPH E., 484 E. Barber Ave., Woodbury, New Jersey (S. McCarthy Avenue, Mantua, New Jersey)

NEW MEXICO

NEVILL, RICHARD A., 723 West Silver Ave., Albuquerque, N. M. (Lone Star Gas Co., Ft. Worth Divn., 908 Monroe, Fort Worth, Texas)

NEW YORK

BEADELL, DONALD A., General Aniline and Film Corp., 435 Hudson Street, New York 14, New York (Product Development Dept., 22 Center Square, Easton, Pa.)
PETERKIN, DON W., Metallizing Engineering Co., Inc., 38-14 30th Street, Long Island City 1, New York (3431 South Ashland Ave., Chicago 8, Ill.)

OHIO

FRANK, JOHN A., 820 Ludlow Avenue, Cincinnati 20, Ohio (John A. Franek)

OKLAHOMA

CARMICHAEL, MILES, Cathodic Servicing Company, 3607 So. Lewis Place, Tulsa, Okla. (134 Heavy Trafficway)
RISELING, T. M., Cathodic Equipment Co., Inc., Rogers & Wright Bldg., 216 W. Second St., Tulsa, Oklahoma (Cathodic Servicing Company, 134 Heavy Trafficway)
WITCHER, HENRY A., Box 521, Tulsa, Oklahoma (Sinclair Oil & Gas Co., Box 794, Ozona, Texas)

PENNSYLVANIA

MADIGAN, JAMES F., Rohm & Haas Co., Cor. Lab., Semi-Wks. Dept., 5000 Richmond St., Philadelphia, Pa. (Sperry Gyroscope Company, Great Neck, New York)
RUTTER, CHARLES M., JR., Equitable Gas Co., 422 Blvd. of Allies, Pittsburgh 19, Pa. (610 Wood Street, Pittsburgh 22, Pa.)

SOUTH CAROLINA

PERMAR, PHILIP H., 1004 Hitchcock Dr., Aiken Estates, Aiken, S. C. (329 Nichols Ave., McDaniel Crest, Wilmington, Del.)

TEXAS

CAMPBELL, A. B., Natl. Assn. of Corr. Engineers, 1061 M & M Building, Houston 2, Texas (919 Milam Building)
CARPENTER, G. CAREY, 4026 Parkside Drive, Dallas, Texas (Esso Standard Oil Co., Box 551, Baton Rouge, Louisiana)
CATTS, GORDON R., Mechanical Engineer, 1002 Chamberlain, Corpus Christi, Texas (Egglehof Engineers, P. O. Box 3276)
COLLINS, JAMES H., 337 W. Mariposa, San Antonio 1-B, Texas (415 West Mandalay Drive)
GARNER, CORDELLE L., 3315 Shackett, Houston, Texas (P. O. Box 85, Broussard, Louisiana)
GLENN, DENIS, United Gas Pipe Line Company, P. O. Box 952, Beaumont, Texas (P. O. Box 780, Wichita Falls, Texas)
RHODES, H. A., Transcontinental Gas & Pipeline Corp., Box 296, Houston, Texas (3100 Travis)
SAYE, HUGH A., JR., Electronics Engineering, Inc., 2708 Suffolk Drive, Houston 6, Texas (Harco Corp., 2001 Harold, Houston 6, Texas)
SNYDER, KENNETH T., Atlas Mineral Products Co. of Pa., Inc., P. O. Box 15034, Houston 1, Texas (Box 252)

WASHINGTON

KETCHAM, BROWER, 1931 2nd Avenue, Rm. 212, Seattle 1, Wash. (915 Franklin St., San Francisco 9, Cal.)

WISCONSIN

KEDZIE, DONALD P., 2134 West Walnut St., Milwaukee, Wis. (3819 So. Hanson St.)

FOREIGN

LEBLANC, ROLAND L., Lago Oil & Transport Co., Ltd., Box 42, Aruba, N. W. I. (Cities Service Refining Co., 1213 Bernard, Pasadena, Texas)
FLORES, ING. LEOPOLDO NETTEL, Calle Alamo 203 Esq. Con. Chairel, Tampico, Tamps., Mexico (E. Garranza 1012 OTE. 2DO. Piso.)
FRENCH, JOHN D., 3747 Coronet Road, Apt. 11, Montreal, Quebec, Canada (Corrosion Services, Ltd., 77 York St., Toronto, Ontario, Canada)

NEW NACE CORPORATE MEMBERS

The International Nickel Co. of Canada, Ltd.
Toronto 1, Ontario, Canada
R. J. Law, Representative

National Pipe Coatings, Inc.
Los Angeles, California
Raleigh P. Nelson, Representative

Trans-Northern Pipe Line Company
Toronto, Ontario, Canada
A. N. Horne, Representative

Please Send in
NEWS
for September Issue
of CORROSION
to Reach Central Office
Before
AUGUST 10

NEW PRODUCTS —Materials—Service—Literature

Metalweld, Inc., Philadelphia, Pa. has published a 6-page folder describing "Metalweld Plasticote," a non-porous insoluble lining that can be applied to internal surfaces of hot water generators and storage tanks to protect them against corrosion. Application requires only 24 hours, and the manufacturer claims it will reduce maintenance cost by eliminating annual reconditioning of tanks that become corroded and pitted.

•

The Steel Shipping Container Institute, Inc., 600 Fifth Ave., New York 20, N. Y. has issued a directory of manufacturers who produce more than 90 percent of the steel shipping containers. Plant locations and types of containers manufactured, statistics on annual production and a brief history of the industry are included.

•

A New Summary chart compiled by Steel Founders' Society of America gives standard specifications for more than 70 designated classes of steel castings. Copies may be obtained from F. Kermit Donaldson, executive vice-president, Steel Founders' Society of America, 920 Midland Bldg., Cleveland 15, Ohio.

•

A New Coal Tar base enamel quantity calculator is being issued by Reilly Tar & Chemical Corp., 1615 Merchants Bank Bldg., Indianapolis, Ind. Estimates for quantities of enamel, primer and coupling compound are given, along with recommended temperatures of application of enamel and estimates for drying time on primer. On the reverse side is a Manheim type slide rule with the C, D, CF, DF, A and B scales, with a hairline plastic slide.

•

J. L. Collins has published a 4-page data sheet describing copper sulfate electrodes, galvometers, a single-rod soil resistivity apparatus and a price list. Address is J. L. Collins, Angleton, Tex.

•

The Babcock & Wilcox Co. has announced the installation of machinery for employing the Ugine-Sejournet hot tube extrusion process. The method, developed in France, is expected to result in great savings of time and money, particularly in the field of unpierceable metals such as molybdenum, and some of its alloys, titanium and certain stainless steels which are difficult or impossible to pierce. With the new equipment, a white hot billet of metal 28 inches long by 8 inches in diameter can be extruded into a 60 foot tube, 2 inches in diameter in less than 5 seconds.

•

Nathaniel Hall Co., a newly formed consulting engineering firm has opened offices at 239 Waverly Ave., Brooklyn, N. Y. The firm specializes in the fields of metal finishing, electrodeposition and allied processes.

•

Knapp Mills, Inc. has developed a lead clad steel leg for supporting lead cooling coils used in processing corrosive acids. Lead clad steel legs reduce weight, cost of metal, cost of installation of the lead legs and obviate failure of lead legs due to temperature changes. The lead is chemically clad to the steel and expands and contracts with the steel with temperature changes.

•

The Nooter Corp., St. Louis, Mo., has established the St. Louis Metallizing Co. Formerly the Metallizing Division of the Nooter Corp., the newly formed company will retain the same personnel, equipment and management. Among other things, the firm's metallizing process applies corrosion resistant metallic coatings to structures and equipment. Officers of the company are Walter B. Meyer, president; Joseph A. Peressin, vice-president; Raymond Craven, vice-president and Elmer Smitt, secretary-treasurer.

•

A Brief, 2-page, 3-color Bulletin is now available on the Ess Smoke Recorder for the use of plant and combustion engineers interested in recording stack smoke density and combustion performance. Wiring and installation diagrams are included in Bulletin 512. The firm is at Bergenfield, N. J.

•

La Favorite Rubber Manufacturing Co., 264 Wagaraw Rd., Paterson, N. J. claims developments in lining and covering pipe, fittings and process equipment with rubber which reduce maintenance costs, prolong life of pipeline and process equipment, protect equipment investment and conserve space. The firm says that special designs of bent pipe and shapes can be lined with rubber without risk of failure.

•

Dow-Corning Corp., Midland, Mich., describes "Dow Corning Valve Seal A" in a 4-page brochure. The product is especially suited for use where superior chemical resistance, combined with exceptional heat stability, oxidation resistance and water repellency is required, the company says. The brochure states consistency remains relatively constant over a temperature span of more than 500 degrees F, from —40 degrees to over 500 degrees F. It will not carbonize at any temperature and is highly water repellent.

•

The V. D. Anderson Co., 1935 West 96th St., Cleveland 2, Ohio, is marketing a new downflow purifier which it is claimed will remove 99 percent of all entrainment from the flow stream. The firm states their product, "Hi-eF Purifiers" carries a guarantee to the boiler industry to deliver vapor with 1.0 PPM or less of total solids. Removal of foreign matter is accomplished by means of a multi-stage centrifugal element.

•

Polyken Industrial Tape, Dept. of Bauer & Black, Div. of the Kendall Co., 222 W. Adams St., Chicago, Ill., has developed a tape that is virtually 100 per cent waterproof. It took 10 years of intensive research to produce the tape to meet rigid armed forces specifications, the firm maintains.

•

The Bristol Co., Waterbury 20, Conn., announces new factory facilities for making arc welded diaphragms of extremely thin stainless steel, Ni-Span C, and phosphor bronze. Diaphragms from 0.0015 to 0.005 of an inch can be arc welded.

The International Nickel Co., Inc., 67 Wall St., New York, N. Y. has published a 32-page booklet titled "Corrosion Resisting Properties of the Austenitic Chromium-Nickel Stainless Steels." The booklet gives the results of tests on numerous austenitic stainless steels in various solutions, acid, neutral and alkaline. It covers in general the mechanism of corrosion resistance in stainless steels, factors affecting their corrosion, behavior in various corrosive environments, marine and industrial atmosphere, in organic and inorganic acid salt solutions and in halogen salts and weak and strong bases. Preferred practice in construction and use of stainless steels is also given.

•

"Penetrol" a liquid rust preventive in use for more than 50 years in bulk form is now being marketed in a 12-ounce aerosol dispenser. The makers say "Penetrol" uses dry rust as a pigment to build an iron oxide primer, and that the only surface preparation needed is to remove loose rust scale, and clean the surface of oil and grease.

•

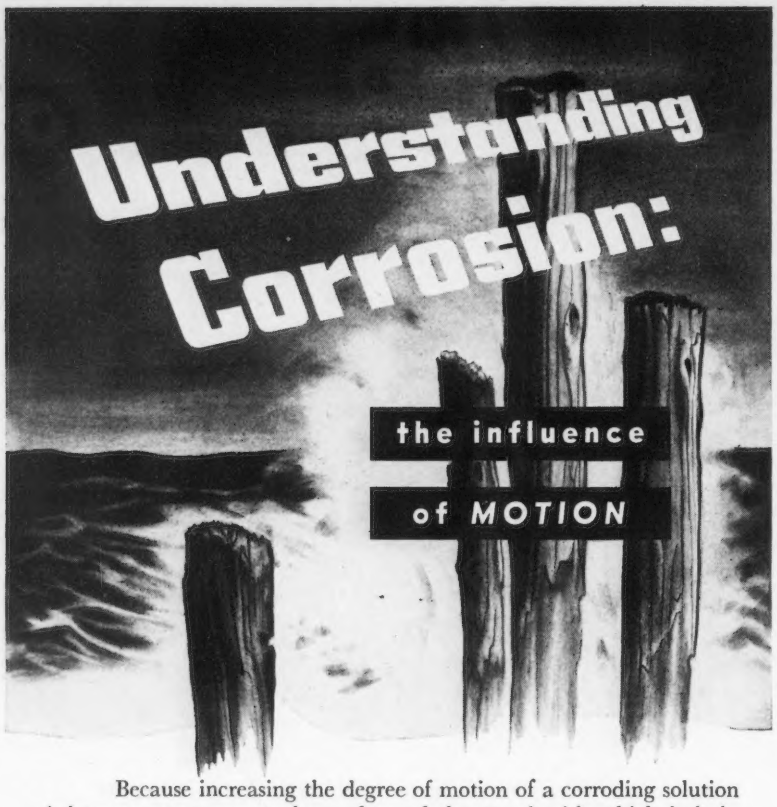
Nielco Laboratories, P. O. Box 4703, Detroit 19, Mich. has published a 16-page booklet describing "Nielizing," the firm's corrosion control process. The firm says the process cleans not only the surface of the metal, but goes deep into the pores to remove oxides imbedded there and changes the surface to a non-active state. The process is far superior to normal phosphatizing, the firm claims. The non galvanic surface produced on some metals has withstood atmospheric environments for two years. After being "Nielized," bare metal withstood 12 hours exposure in a salt fog cabinet before any sign of corrosion set in, the originator of the process claims.

•

Texsteam Corp., 320 Hughes St., Houston, Tex. is now handling sales of Texsteam safety valves, chemical injection pumps, Vapor-Clarkson steam generators and other products. Formerly, Bettis Corp. of Houston was the sales agency. The Houston plant has been enlarged, new machines installed, and changes recommended by safety engineers have been made. The firm plans to build more warehouse space and office facilities.

•

Rosson-Richards Co., M & M Building, Houston, Texas, a pipe line corrosion protection firm, has started a metallizing division. By spraying molten metal, usually zinc or aluminum, on structures, a coating is obtained which in some cases will limit corrosion for 20 years or longer. Sand blasting is used as surface preparation. Because of its long life, metallizing reduces the expense of periodic cleaning and refinishing of surfaces. Zinc or aluminum metallizing, because of a tight bond, reduces oxidation under the coating and provides the electrolytic protection when applied to iron or steel. Nonferrous metals also may be protected by metallizing. Metco equipment and systems are being used by Rosson-Richards Co.



Because increasing the degree of motion of a corroding solution brings more oxygen to the surface of the metal with which it is in contact, such increase has a decided influence on the rate of corrosion. In liquid that may appear quiet, convection currents are nonetheless at work slowly distributing dissolved oxygen throughout the solution. When velocity agitates the liquid-air interface, unsaturated liquid is brought to the surface layer and the oxygen-solution rate rapidly stepped up. At the same time the liquid film on the surface of the metal is thinned so that this increased amount of dissolved oxygen diffuses more readily. Thus the combined effect of more dissolved oxygen conveyed more rapidly to the metal is a marked acceleration of corrosion.

Velocity, too, is often the indirect if not the direct cause of mechanical erosion of metal, for the deterioration it helps bring about results in the formation of corrosion products. In a quiet system these might serve a protective function but with motion a factor they erode readily, leaving already weakened metal exposed to further corrosive attack.

The ever-varied interplay of its many governing factors render the mechanism of corrosion complex indeed. Recognizing effects, determining causes, and controlling those that can neither be eliminated nor regulated is a responsibility industry has long assigned to Dampney. The reduction of *your* corrosion problems through the medium of Dampney equipment-engineered protective coatings . . . formulations of vinyls, ceramics, asphaltums, silicones, chlorinated rubber and other natural and synthetic resins . . . is a responsibility we should likewise welcome.

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THE DAMPNEY COMPANY

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PERSONALS

E. J. Hamner has been appointed manager of operations in California for Humble Oil & Refining Co. John S. Bell was appointed assistant manager for the company's California operations. Hines H. Baker, president of the firm, announced the appointments recently. Mr. Hamner and Mr. Bell will have full responsibility for all California operations with Hunter Yarbrough as area geologist in charge of exploration matters and Lawrence H. Byrd as area production superintendent in charge of drilling and producing. Mr. Hamner received a BS in geology and an MS in petroleum engineering from the University of Oklahoma in 1932. He started to work for Humble as a summer-time employe. Mr. Bell, also a graduate of the University of Oklahoma, joined Humble in 1933. Mr. Yarbrough is a graduate of the University of Texas with a BS in geology. He has been with Humble since 1940. Mr. Byrd is a graduate of A. & M. College with a chemical engineering degree. He joined Humble in 1937. In 1951 he was made assistant district superintendent at Los Angeles, Calif.

•

Wayne A. Johnson, formerly with Cathodic Protection Service, and the Texas Pipe Line Co., has formed "CORECO," the Corrosion Rectifying Co., 1506 Zora St., Houston 24, Texas. Mr. Johnson has been a member of NACE since 1948. After receiving his BS degree in physics from Texas A & I College in 1947 he took a position with the Texas Pipe Line Co. He was associated with Cathodic Protection Service for a year prior to establishing his own consulting firm.

•

K. A. Spencer, B. Sc. Tech., A. M. I. Chem E., Assoc. M.C.T., is instituting a consulting corrosion engineering practice with special emphasis on coating materials and application of cathodic protection. His addresses will be: 5 Greencourt Rd., Petts Wood, Kent, England; and 40 South St., London, W.1., England.

•

Myron Ceresa has been appointed manager of electroplating projects for the Special Products Development Division of the Westinghouse Electric Corp. Mr. Ceresa will be in charge of laboratory operations, including development, pilot plant and technical service work.

•

Ladish Co., Cudahy, Wis., has announced the appointment of **Richard M. Bode** to an executive sales position in its Valve and Fittings Division. Mr. Bode is in charge of marketing a new line of forged steel valves the company is introducing. He was formerly with the Tri-Clover Machine Co. as vice-president and sales manager.

•

J. C. Fink has been appointed engineering manager of industrial products for the Westinghouse Electric Corp. He will coordinate the engineering activities of all the industrial products divisions. He formerly was assistant to the vice-president in charge of engineering. He has been with Westinghouse since 1928, a year after he graduated from Pennsylvania State College.

Corrosion Abstracts

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1. GENERAL

1.2 Importance

1.2.2, 1.7.1

Corrosion Mitigation Discussed at United Nations Meet. Systematic Research Urged by Speakers as Means of Reducing Huge Economic Losses. W. BECK. *Corrosion*, 6, No. 4, 19-21 (1950) Apr., News Section.

Corrosion control was discussed in a number of papers at the United Nations Scientific Conference on the Conservation and Utilization of Resources at Lake Success Aug. 17-Sept. 6, 1949. W. H. G. Vernon considered the cost of corrosion and its control in relation to the world shortage of metals and the increasing demand on the world's metal resources. It is more economical to protect structural steel parts by a coating than to over-design their thickness, and coated, low-alloy steels are more economical than stainless steels. U. R. Evans discussed the role of protective coating in metal conservation, treating in detail the possibilities of cathodic and anodic coatings. Coatngs containing 25 percent of metallic zinc are very effective for steel and may be obtained by using chlorinated rubber or polystyrene highly pigmented with zinc dust. Abstracts of several other papers on corrosion are also presented.

1.7 Organized Studies

1.7.1, 2.3.9, 2.4.3

Symposium on Ultrasonic Testing. Am. Soc. Testing Materials, Philadel-

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CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W.1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

phia. Special Technical Publication No. 101, 133 pages. 1951.

Includes an introduction by H. C. Amtsberg, and the following papers: 1) "Ultrasonic Wave Propagation in Materials: A guide to Theoretical Results," Louis Gold; 2) "Inspection Processing, and Manufacturing Control of Metals by Ultrasonic Methods," Carlton H. Hastings and Seymour W. Carter; 3) "Basic Principles of Practical Ultrasonic Testing." John C. Smack; 4) Ultrasonics in the Heavy Forging Industry," James C. Hartley; 5) "The Application of Ultrasonics to the Fabrication of Aluminum," J. V. Carroll; 6) "Ultrasonic Testing in Railroad Work," E. D. Hall; 7) "Ultrasonics in the Electrical Industry," D. M. Kelman; 8) "Ultrasonic Testing of Bronze Forgings and Ingots," A. Piltch; 9) "Pulse Techniques Applied to Dynamic Testing," J. R. Leslie; 10) "The Measurement of Dynamic Modulus in Adhesive Joints at Ultrasonic Frequencies," A. G. H. Dietz, P. J. Closmann, G. M. Kavanagh, and J. N. Rossen. Symposium is concluded by a general discussion.—BLR.

1.8 Personalities

1,8, 1.2.2

Corrosion Mitigation Viewed by Management. H. H. ANDERSON. Shell Pipe Line Corp. Paper before NACE, North Texas Sec., Dallas, Feb. 26, 1951. *Petroleum Engr.*, **23**, No. 4, D30-D34 (1951) Apr.

Corrosion prevention as viewed by management. Recent analysis showed that the cost of corrosion to the U. S. is about 5½ billion dollars per year. Part of the fault lies with management in their failure to recognize the direct losses from corrosion and to connect its many indirect causes with their cause. Author cites the excellent work of the NACE and urges companies to join the association as an aid towards solving their corrosion problems. Today the conservation of metal is a national requirement instead of merely an economic desirability.—INCO.

2. TESTING

2.2 On Location Tests

2.2.2, 6.3.15, 6.3.20

Corrosion and Mechanical Properties of Titanium and Zirconium at Normal Temperatures. Naval Engineering Experiment Station, Annapolis. W. LEE WILLIAMS. [nd.] 47 p. (EES-C-3395-B-C-3501-C.)

Data contained herein expand on the work presented previously in Report C-3395-B dated 9 February 1950. The titanium and zirconium materials investigated represent metal consolidated by powder metallurgy and by several melting processes. These in turn reflect various impurity levels, especially of the carbon. The chemical compositions and tensile properties are reported. Corrosion tests are included for long exposure periods in a marine atmosphere and in quiet sea water (fouling conditions). Other corrosion tests include those in slowly moving sea water for titanium with and without coupling to various other metals. Data are presented concerning the resistance of titanium to hydraulic cavitation resistance. The very high order of resistance to marine corrosion continues to be particularly attractive. Further fatigue tests are reported on notched and unnotched specimens. Good fatigue properties, with high endurance ratios, continue to be found with the melted product. Of particular interest is the discovery that the resistance to salt-water corrosion fatigue is very nearly equal to the fatigue strength in air; the salt-water corrosion-fatigue properties seem to be superior to those for any other known structural alloy. The tests of the 2½ percent chromium-1 percent iron alloy demonstrate the superior properties to be realized by titanium alloys. In the annealed condition, properties of this particular alloy were as follows: tensile strength, 132,000 psi; yield strength, 116,000 psi; endurance limit, 71,000 psi; elongation, 22 percent; reduction of area, 51 percent.—NSA.

2.2.2, 6.4.4, 6.6.11

Tropical Exposure Tests on Magnesium Alloy in the Presence of Wood. H. G. FARNBOROUGH, Gt. Brit. Royal Aircraft Establishment. (Report Met 44) October 1949. 21 p., plates, tables.

Magnesium alloy castings protected by a wide range of treatments were bolted inside slightly ventilated boxes of duralumin or wood, representing metal and wood aircraft, respectively. The boxes were exposed 14 months to inland tropical conditions at Nigeria.

The castings in the duralumin boxes corroded very little, even when unpainted. Corrosion of painted castings in the wooden boxes was visible after four

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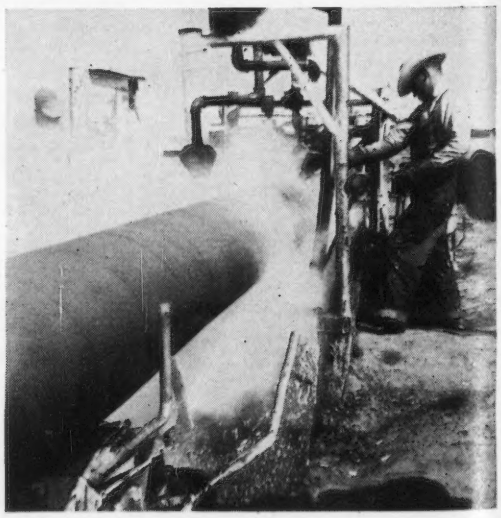

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A.S.T.M. Specification B190-45T classifies the 25-12 alloy into two categories according to magnetic permeability: Type I, having a range of 1.05-1.7 and Type II, having a maximum of 1.05, after holding for 24 hours at 2000° F. and water quenching. Since strength and ductility vary inversely at high temperatures, Type I containing ductile ferrite is able to resist fracture due to sudden overloads by yielding slightly under these stresses, but it has relatively low creep strength. Type II is completely austenitic and has high creep strength under conditions of constant loading, but is not as resistant to sudden shock.

Of major importance in heat applications is the influence of structure on its properties. The amount, form and distribution of the carbides affect strength and ductility and are determined by the percentage of carbon present in the alloy, the temperature, and the time of holding. Of perhaps greater importance is the presence of ferrite in the structure. While it enhances ductility at elevated temperatures after short-time aging, it must be discounted if the alloy is to be exposed for extended periods at the intermediate temperature range of 1200-1700° F., as this range favors the formation of a sigma phase which is hard and brittle. Its presence may result in reduced strength, ductility, and especially thermal fatigue cracking resistance. Thus there is much less tolerance for suddenly applied stress overloading or rapid temperature changes. Continued service about 1700° precludes this sigma formation.

To estimate ferrite on the basis of chemical analysis the Alloy Casting Institute suggests the following formula.

$$\text{R.F.} = \frac{[\%\text{Cr} + 3\,(\%\text{Si} - 1)] - [\%\text{C} \times 16]}{\%\text{Ni}}$$

A ratio factor less than 1.7 denotes a negligible amount of ferrite or sigma and corresponds to the A.S.T.M. limit in permeability value of 1.05. A ratio factor of 1.7-1.85 denotes 2-7%, a ratio factor above 1.85 denotes above 7% of ferrite or sigma.

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months exposure, but remained confined to edges and corners. Corrosion of unpainted specimens in the wooden boxes was visible after 1-4 weeks and by 14 months was appreciable on some castings.

The corrosive effect of birch plywood was approximately 3 times that of spruce plywood, probably because of the greater mold growth on the birch. All the magnesium alloy castings corroded where they were in direct contact with either wood, in spite of the presence of a jointing compound.

Zinc shims in conjunction with a barium chromate—pigmented long oil paste eliminated attack; aluminum alloy MG3, synthetic rubber, and paxolin greatly reduced it. The use of shims between magnesium alloy and wood is considered essential.

The various degrees of protection afforded magnesium alloy castings by different surface and protective treatments in the presence of wood under inland tropical conditions were on the same order as those found by the R.A.E. intermittent sea water spray test, which represents severe marine temperate conditions. Chromate treatments provided considerable protection; machined surfaces were less attacked than cast surfaces. Grit-blasting accelerated attack on cast surfaces. High-purity alloys corroded less than those of normal purity.

Wood appreciably accelerated corrosion of unpainted plated steel nuts and bolts, although the shanks of bolts passing through the wood in the presence of a jointing compound (barium chromate—pigmented long oil paste) were scarcely attacked. Cadmium plating passivated was the most effective plating treatment, followed, in order of decreasing efficiency, by cadmium plating, zinc plating passivated, and zinc plating.

Bimetal corrosion of magnesium alloy by shims or by plated nuts and bolts was slight.

It was concluded that magnesium alloy parts sent to the tropics should receive full protective treatment and should be separated from wood by zinc shims or by neutral organic materials that do not support mold growth. The crates should be well ventilated, and the inside of the crate should not be coated with lime paste, which ultimately accelerates corrosion.—PDA.

2.3 Laboratory Methods

2.3.2, 3.2.2, 6.2.1

An Experimental Contribution to Drop Corrosion. (In German.) F. Blaha. *Monatsh.*, **82**, 170-175 (1951) Feb. 15.

Describes experiments made to investigate the differential aeration theory of ferrous corrosion caused by drops. The experiments were made with drops of different solutions between the poles of an electro-magnet and "aerated" by different gases. Observed phenomena are discussed, the apparatus is illustrated and data are graphed.—BLR.

2.3.2, 5.4.5

Accelerated Weathering of Paint and Varnish Films. P. J. Gay. *J. Oil Colour Chemists' Assoc.*, **34**, No. 368, 43-57 (1951) Feb.

The author states that the breakdown of paint films during weathering is due to degradation of their polymer structure with the result that they are no

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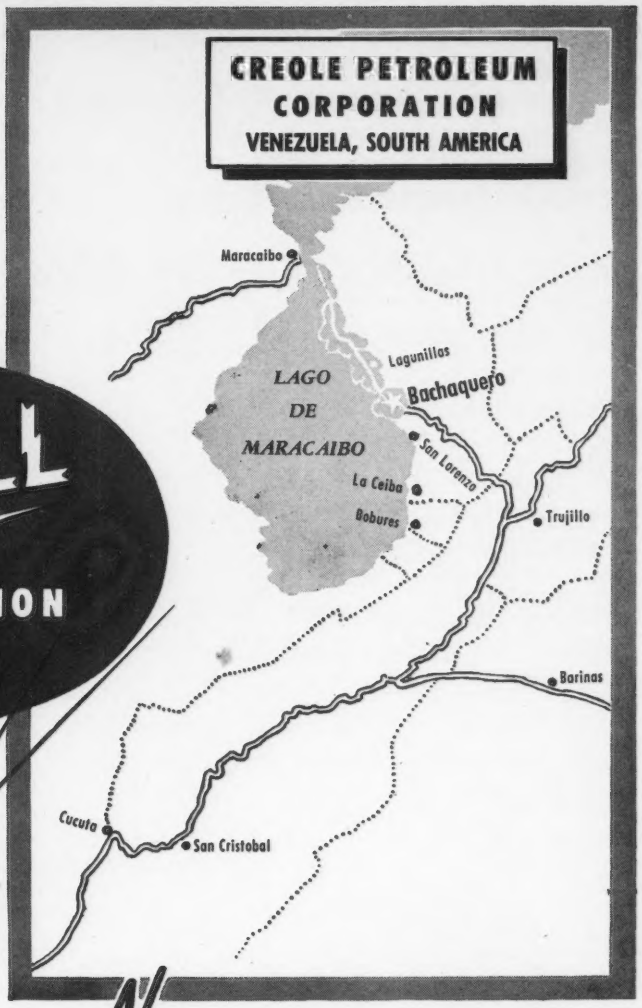

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longer able to withstand the physical stresses resulting from temperature changes and water absorption. He reviews the development of apparatus to hasten this degradation and to impose physical stresses of a high order on the paint film. The new equipment recently installed at the Paint-Research Station is described in detail, as are the results of several experimental cycles carried out with it. Treatment of paint films with oxygen at high pressures has given promising results in causing breakdown similar to that obtained outdoors. Appendices give details of the standard accelerated weathering procedure and a list of references to literature on the subject.—ZDA.

3. CHARACTERISTIC CORROSION PHENOMENA

3.4 Chemical Effects

3.4.6, 3.5.9, 6.2.2

The Mechanism of Scale Formation On Iron at High Temperature. D. W. DUNNINGTON, F. H. BECK AND M. G. FONTANA. The Ohio State University. *Corrosion*, **8**, No. 1, 1-13 (1952) Jan.

A new mechanism of high temperature oxidation of iron is proposed. Diffusion of lattice vacancies in the iron is shown to influence the type of oxide that forms. It was found that with thin specimens an adherent film grew on one side and a loose film on the other. The adherent film followed the parabolic law. The loose film grew in a pseudo-linear manner. The formation of these two types of films is shown to be necessary from consideration of diffusion of iron through the metal and oxide lattices. Applying the same principles to large specimens it is shown that a different kind of oxide layer forms which was observed by Pfeil.

Photographs of magnetite slowly cooled from a high temperature indicate that a plate-like precipitate of ferric oxide forms on the (111) planes of the magnetite.

A brief study was made of blistering. It is demonstrated that superficial blisters form on heating in air and photographs show the later positions of the blisters as the oxide layers grow thicker.

3.5 Physical and Mechanical Effects

3.5.3, 6.4.5, 2.4.2, 2.3.7

Erosion and Heat Transfer With Liquid Metals. Babcock and Wilcox Co. Progress Report V, April 16-May 17, 1950. May 18, 1950. 9 p. (NEPA-1423)

Work has continued on calibration of flowmeters to be used in heat-transfer studies with lithium. The lithium melt-pot charging apparatus has been completed. An electromagnetic pump to be used in lithium-erosion studies was designed and tested with mercury, and a second pump is now under construction. An isothermal erosion loop for operation with lithium at 1000° F. was designed and is ready for operation. Fire-extinguishing agents were tested for reaction with burning lithium. An apparatus to compare the electrical resistivities of lithium and stainless steel for purposes of flowmeter and pump design is now under construction. A sam-

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pling device for use in the test loop is described.—NSA.

3.5.5, 5.4.5

The Blistering of Paint Films. Part II. Blistering in the Presence of Corrosion. J. E. O. MAYNE. *J. Oil Colour Chemists' Assoc.*, **33**, 538-547 (1950) Dec.

An examination was made of the contents of blisters in a film of plasticized polystyrene applied to steel and immersed in sea-water. The blisters contained liquid, but no gas. Movement of water through membranes of polystyrene were examined under both concentration and potential gradients. It was concluded that the blisters grow mainly by electroendosmosis, although 4 percent or more of the contents may be due to hydration or ions, and osmosis may account for a further 6 percent. 13 references.—BLR.

3.5.5, 5.4.5

Corrosion Protection by Polar and Non-Polar Coatings. Parts I & II. E. MANEGOLD. *Fette u. Seifen*, **52**, No. 10, 581-587; No. 11, 675-681; No. 12, 725-728 (1950).

The passage of small molecules and ions through film-forming materials is considered in relation to the porosity, the chemical properties, and the electrochemical structure of the solid matrix. The concept of permeability for numerous geometrical spacings of pores in a matrix is introduced mathematically, and it is shown how experimental data on the permeabilities of collidion and similar membranes indicate pore structure. The electrochemical properties of the matrix determine whether the membrane is permeable to cations or anions, and are expressed in terms of the diffusion, dialysis and Donnan membrane types of potentials. The selectivity of coating materials for cation or anion migration determines both the amount and the site of metallic corrosion and it is illustrated how the combination of cation- and anion-impermeable materials in a protective coating can control and reduce corrosion. Complete inhibition of corrosion cannot be achieved in this way unless the coating is also impermeable to non-ionic molecules, e.g., O_2 and water vapor. The corrosion-protective properties of non-polar coatings, which allow migration of both cations and anions, and of amphoteric coatings, which behave according to their isoelectric points and the pH of the environment, are discussed.—RPI.

3.6 Electrochemical Effects

3.6.2, 6.2.5, 4.6.11

Effectiveness of Cathodic Currents in Reducing Crevice Corrosion and Pitting of Several Materials in Sea Water. THOMAS P. MAY AND H. A. HUMBLE. Paper, Seventh Annual Conference, Natl. Assoc. Corrosion Engrs., New York, N. Y., March 13-16, 1951. *Corrosion*, **8**, No. 2, 50-56 (1952) Feb.

Crevice corrosion and pitting occur when chromium bearing stainless steels, chromium-nickel stainless steels and nickel are immersed in quiet sea water. The crevice corrosion on these materials is of the oxygen concentration cell type of attack. The pitting of these materials is usually severe in sea water. Monel in quiet sea water suffers slight, shallow pitting attack which usually is arrested before deep penetration occurs.

Experiments were conducted in sea water at Kure Beach, N. C., to determine the effectiveness of cathodic current in reducing these forms of corrosion. Test specimens were coupled to magnesium anodes with appropriate resistors in each circuit to control the currents. Potential measurements were made during the course of two runs of four and six months respectively.

Cathodic current in quiet sea water reduces pitting and crevice corrosion on Types 410 and 430 stainless steels but its use is impractical because it causes severe blistering when the current is sufficient to eliminate the corrosion. This blistering is due to hydrogen which is formed on the cathode surfaces by the current. Hydrogen is also generated on mild steel surfaces but does not ordinarily produce blistering.

Cathodic currents effectively reduced these forms of corrosion on nickel, Monel and Types 302 and 316 stainless steels without the development of blisters even at 30 ma per sq. ft.

3.6.5, 3.6.8

Mechanism of Oxygen Reduction at an Iron Cathode. WALTER A. PATRICK AND HERMAN B. WAGNER, Johns Hopkins University. *Corrosion*, **6**, No. 1, 34-38 (1950) Jan.

Mechanism of the anodic corrosion process is discussed. The paper refers to previous articles wherein hydrogen peroxide was assumed to be an intermediate in the corrosion reaction, particularly where ferrous materials are involved. Discusses experiments with iron-amalgam cells with a description of the procedure and diagrams of apparatus. Tables are included which present data on current, current density, percent absorption upon cathode solution and percent yield of hydrogen peroxide. An inspection of these data show that the greatest yields of peroxide were obtained in alkaline solutions with small current densities. Results indicate that possibly hydrogen peroxide also was formed in the acidic solutions but was more quickly reduced further to the hydroxylion which reacted to form water. A possible explanation is given of the instability of hydrogen peroxide in the acid as contrasted to its greater stability in the alkaline solution. Results obtained with those from previous parallel experiments are compared.

3.6.5, 6.3.6, 6.3.9

The Use of Copper and Galvanized Steel in the Same Hot Water System. Gt. Brit. Dept. of Scientific & Industrial Research, Building Research Station, Watford. (Digest 8) July 1949. 3 p., diagr.

Failure of galvanized steel hot-water tanks in association with copper pipes occurs after a short time in certain areas. Some types of water, particularly water rich in carbon dioxide, dissolve minute quantities of copper from the pipes of a hot-water system, although the loss in weight is difficult to detect and the life of the pipes is not thereby impaired. When the water containing dissolved copper comes in contact with the tank, however, some of the copper is deposited on the zinc and an equivalent amount of zinc is dissolved. The continuous electrolytic action between the two metals (dezincification) causes rapid localized attack leading to ultimate perforation of the zinc coating. Rusting of the bared steel base then proceeds until the tank eventually leaks.

The significance of this mechanism lies in the minute amount of copper sufficing to start it. As little as 0.1 ppm in the water may lead to serious damage. An increase in carbon dioxide content of a particular water increases its cupro-solvency, but an increase in temporary hardness may decrease cupro-solvency because of the formation of protective carbonate scales. Unless a high temporary hardness is accompanied by very low carbon dioxide content, a pitting type of attack may develop. Water softening, which may slow up or stop scale formation, should not be carried too far with a bimetal system. In addition, since cupro-solvency increases with rise in temperature, vigorous heating, particularly in the early life of an installation, should be kept at a minimum until a protective scale forms.

Unless local experience shows it safe to use copper and galvanized steel together, an all copper or an all-galvanized system should be installed, depending on the nature of the water supply. From the standpoint of corrosion resistance, an all-copper system is generally preferable.

Failures of bimetal cold-water cistern installations are rare; most of them can be ascribed to the introduction of hot copper-bearing water by splashes from vent pipes or by expansion via the feed pipe. As precautions, the expansion pipe should not discharge against the side of the cistern, and the drawoff for cold water feed to the hot water tank or cylinder should project slightly into the cistern. Coating the cistern with a bituminous paint that does not pollute the water gives additional protection.—PDA.

3.7 Metallurgical Effects

3.7.4, 6.2.2, 6.2.3

Influence of Hydrogen on Elasticity of Iron and Steel. (In French.) PAUL BASTIEN AND PIERRE AZOU. *Compt. Rend.* (France), **231**, 147-148 (1950) July 10.

The influence of hydrogen on the elasticity of iron and steel was experimentally investigated, hydrogen being introduced into iron or very mild steel by electrolysis or other means. Analysis of the results indicates that the influence of hydrogen on elastic properties is only slight and of secondary importance compared to effects on plastic deformation leading to fracture.

4. CORROSIVE ENVIRONMENTS

4.3 Chemicals Inorganic

4.3.2, 2.1.1

The Dissolution of Metals Over the Temperature Range 25° C. to —60° C. I. The Dissolution of Magnesium in Hydrochloric Acid-Methyl Alcohol-Water Solutions. A. B. GARRETT AND R. R. COOPER. *J. Phys. & Colloid Chem.*, **54**, 437-444 (1950) Apr.

Series of investigations is designed to show the general characteristics of the dissolution of metals in hydrochloric acid from 25 to —60° C. From the data, order of reaction; rate of reaction at various stirring speeds and temperatures; and temperature coefficient of reaction rate, i.e., activation energy are calculated.—BLR.

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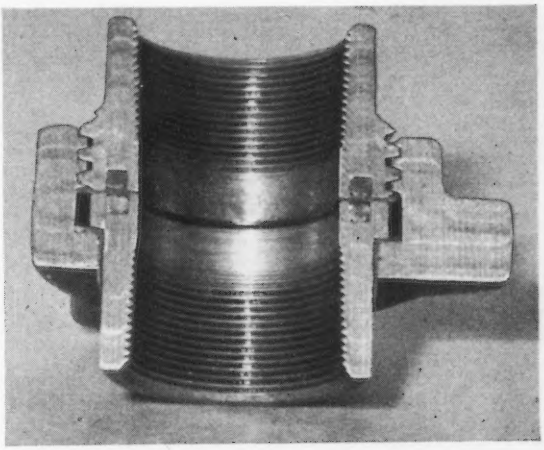

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4.4 Chemicals Organic

4.4.2, 6.2.1, 6.3.1

Corrosion by Some Organic Acids and Related Compounds. H. O. TEEPLE. Paper, Seventh Annual Conference Natl. Assoc. Corrosion Engrs., New York, N. Y., March 13-16, 1951. *Corrosion,* **8,** No. 1, 14-28 (1952) Jan.

In this paper there are discussed the results of corrosion tests in various organic acids, principally those of the lower aliphatic series. Aqueous solutions of the acids and mixtures are considered. Related compounds, such as aldehydes, ketones, esters and anhydrides are also discussed.

The corrosive conditions studied are those which prevailed during the production or use of these compounds. Where appropriate, laboratory test results are included.

The materials of construction discussed are the ferrous and non-ferrous alloys. These include the stainless steels, the special austenitic stainless steels, copper and copper-base alloys, nickel and nickel-base alloys.

4.6 Water and Steam

4.6.2, 7.6.4

Sulfite and Silica in Boiler Water at Springdale. L. E. HANKISON AND M. D. BAKER. *Trans. Am. Soc. Mech. Engrs.,* **72,** 505 (1950).

Hydrogen sulfide was first detected in gases discharged from air ejector of main condenser of unit at Springdale Station about 6 months after unit placed in service. Investigation indicated that this was probably due to decomposition of sodium sulfite, which appeared to be present in excessive amounts, depositing on boiler tubes, where it decomposed at red heat to give sulfide, which in turn reacted with water to give hydrogen sulfide. Reduction of sodium sulfite concentration did not eliminate hydrogen sulfide production, so acid cleaning was resorted to for removal of deposits, after which boiler was brought to satisfactory operating condition. Severe corrosion due to hydrogen sulfide was noted at discharge throat to condenser, and some corrosion of tubes in air ejector condenser. Erratic results for sodium sulfite analyses were found to be due to use of copper sampling lines, which reduced sodium sulfite. Monel was also reactive, so all sampling lines and condensers should be of steel. Sulfite determination may be in error if samples are collected at or above 80° F. Silica contamination of feedwater system and turbine deposits may occur owing to fly ash that enters open vents.—AWWA.

4.6.3, 5.7.3

Corrosion Control by Deaeration of Mill Water. D. J. PYE. Dow Chemical Co. Paper, N.A.C.E. Section Meet., San Francisco, June 14, 1950. Abstr. *Corrosion,* **6,** No. 9, 3 (1950) Sept.

Severe corrosion and fouling of all-steel tubular exchangers and pipelines at a Pittsburgh, Calif., plant of Dow Chemical Co. was eliminated by deaerating the brackish San Joaquin river mill water used. Equipment life has been increased five fold. Savings amount to $8,700 per year after deducting $5500 for amortization of capital outlay on a 10-year basis.

5. PREVENTIVE MEASURES

5.1 General

5.1, 5.3.1, 5.4.1

Causes and Correction of Finishing Material Defects. II. P. O. BLACKMORE. *Paint, Oil, Chem. Rev.,* 1950, **113,** No. 16, 18, 20, 22, 48, 50-51; No. 17, 19-20, 36-40, 42.

The causes of and cures for the following defects are given: lifting; poor sanding properties; shelving or laminating; excessive orange peel; bridging (across mouldings); dry spray; poor rubbing and polishing characteristics; printing (marking of the surface); blooming; discoloration (yellowing); checking (cold-, humidity- and veneer-checking of wood finishes are distinguished); scratching white; streaking and specking; blushing or blooming in service; flooding and floating; wrinkling; frosting; flatting (of urea/melamine finishes); flaking and peeling; lack of build; poor drying or curing; poor flow; seeding; off-color.—RPI.

5.2 Cathodic Protection

5.2.2, 8.9.5

Magnesium-Alloy Anodes in Ship Protection. *Light Metals Bulletin,* **13,** No. 5, 185 (1951).

A report by K. N. Barnard, published in the Canadian Journal of Research, describes the results of a fourteen-month test of magnesium alloy anodes in water carried out at the Canadian Naval Research Establishment. The current from the anodes was used to protect cathodically an inactive Algerine Class minesweeper. The results indicate that the outer underwater hull of a ship in reserve can be given adequate cathodic protection by the use of magnesium anodes located at two positions 16 feet deep. Anodes need not be placed at or near outlets, etc., as is the practice with the present zinc anodes, which give unsatisfactory protection. It should be practical to prevent the underwater corrosion of steel buoys, rafts and active ships when in harbor. No studies of ships at sea are reported.—TIME.

5.2.3, 1.7.1, 1.8

Objectives of Technical Practices Committee 3—Anodes for Impressed Currents. DONALD H. BOND. Texas Pipe Line Co., Houston, Texas. *Corrosion,* **7,** No. 2, 41 (1951) Feb.

Technical Practices Committee 3 of the National Association of Corrosion Engineers has a basic objective of studying materials which may be used as ground anodes in connection with cathodic protection systems where direct current from an external source is applied. The studies also include backfill. Research and actual field testing are underway, on steel, carbon and graphite anodes, coke breeze, graphite and lime and coke breeze and lime. Tests on five of six installations have been completed. Further studies are planned.

5.2.3, 5.4.5, 4.6.11

Some Effects of Cathodic Protection on Conventional Paints. L. P. SUDRABIN, F. J. LEFEBVRE (Electro Rust-Proofing Corp., Belleville, N. J.), D. L. HAWKE AND A. J. EICKHOFF (National Lead Company, Research Laboratories, Brooklyn, N. Y.). Paper, Seventh Annual Conference, Natl. Assoc. Corrosion Engrs., New York, N. Y., March 11-14, 1951. *Corrosion,* **8,** No. 3, 109-114 (1952) Mar.

The use of cathodic protection with metal protective paints is of interest to industry where steel structures are immersed in water or buried in soil. While both systems of protection offer many advantages, both have some disadvantages. Hence the question, 'Are they compatible and would a combination of the two systems overcome some or all of the disadvantages of each?'

It was felt that with conventional paint systems, blistering could be minimized by applying a constant potential between an anode and the painted surface rather than a constant current. Four groups of tests were set up in fresh and salt water. Details of tests are given.

In fresh water it was noted that blistering of paint increased rapidly with increasing potential measured against the surface of the paint film with a saturated KCl calomel half cell. Although considerable blistering was observed where the potential measured against a calomel half cell did not exceed —850 millivolts, the paint films materially assisted cathodic protection.

In sea water it is also noted that vinyl paint films blistered increasingly with increasing potential pressure across the film. At potentials less than 1000 millivolts measured against a KCl calomel half cell very little if any blistering was encountered after 1½ years over that observed on a panel not under cathodic protection. On cathodically protected panels small pinpoint white deposits formed, indicating effective policing by cathodic protection.

To establish more definitely the best combination of cathodic protection and paint, the study should extend several years beyond the time of initial failure of the paint film.

5.4 Non-Metallic Coatings and Paint

5.4.1, 5.3.1, 5.9.1

Industrial Finishing Year-Book, 1951. Edited by W. F. COXON. Med. 8vo. Pp. 396, illustrated. 1951. Watford, Herts: Arrow Press, Ltd., 157, Hagden Lane, London. (12s 6d.; free to subscribers to Industrial Finishing).

This is the second issue of this yearbook. It is almost twice the size of the 1950 edition, and several of the original chapters have been divided into two or more and a number of new chapters have been introduced. This has resulted in a much more adequate and balanced coverage of the field with which the book claims to deal. The three most important additions from the metallurgist's point of view are those on metal coloring, the finishing of aluminum, and the finishing of zinc alloy die-castings. Metal coatings other than electrodeposits are more adequately covered than in the previous edition, but one hopes that in the 1952 edition even more space will be devoted to such subjects as metal spraying. The chapter on metal polishing is also greatly improved. A bibliography of literature reviews on various aspects of industrial finishing and allied subjects is a welcome feature, but the choice of papers for inclusion in some of these reviews,

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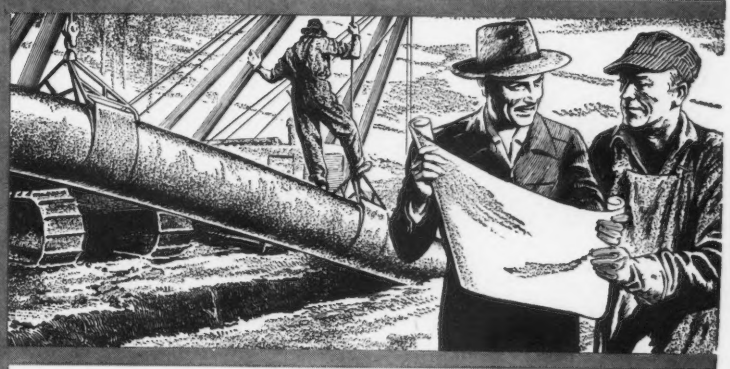

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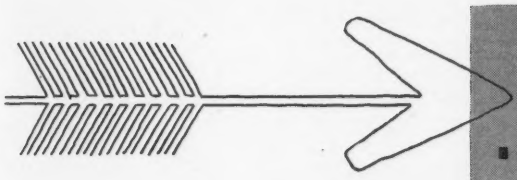

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e.g. that on corrosion, does not appear to have been made very critically. This issue of the year-book is a very great improvement on the 1950 issue and it is now a most useful general reference book.—MA.

5.4.5, 6.4.2

Aluminum Paint. *Foundry* (U. S. A.), **79,** No. 4, 251-252 (1951) Apr.

Speco, Inco., Cleveland, has developed a heat-resistant aluminum paint formulated to withstand temperatures up to 1700° F. (927° C.), with a silicone base. It is said to fuse with surface metal immediately, upon application, and to form a bright, elastic finish resistant to moisture, corrosion, mild acids, alkalis and industrial fumes. It sets in four hours and dries completely overnight on hot surfaces.—ALL.

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1, 8.9.5, 5.8.2

Further Developments in the Burning of Boiler Fuels in Marine Diesel Engines. J. LAMB. *J. Am. Soc. Naval Engrs.,* **63,** No. 1, 201-251 (1951) Feb.

After completing 3 years' service on high viscosity fuels the main engine parts of the Auricula were examined. No measurable wear had taken place in any of the crankshafts, crankpin or crosshead bearing and the steel bearing surfaces were quite free from any suggestion of corrosion. The rubbing surfaces of the cylinder liners were smooth and free from scratches or pitting. Conditions productive to the formation of sulfuric acid in Diesel engines do occur on occasions, but experience with the Auricula and other ships operating on fuels containing high sulfur content has proved that the corrosive effect on any part is negligible, especially in large slow-speed Diesel engines. One examination showed that a yellow deposit on the exhaust valve stems and exhaust gas passages was vanadium pentoxide and not free sulfur as previously supposed. At the present time, a small quantity of potassium bichromate is added to the fresh water used to cool pistons and cylinder jackets in order to prevent corrosion of metal parts. This chemical is a very efficient inhibitor when used in correct proportions. Cast iron has long been the standard material for cylinder liners and piston rings of Diesel engines but not much attention has been given to its wear-resisting properties. Resistance to wear, largely a function of structure rather than hardness, may often be improved by small additions of alloying elements, such as nickel, chromium and molybdenum. Tables and diagrams are included.

7.6 Unit Process Equipment

7.6.4, 6.3.6

Cures Heater Troubles, Saves Money. E. H. ROPER. *Power,* **94,** No. 11, 94-95 (1950) Nov.

Description of how corrosion in water tanks, overheating of water heaters and sealing of boilers was stopped in an industrial process plant. In a new plant, steam is used as the heating medium in the water heaters. Instantaneous heaters which were installed were copper-lined, or made with copper shells and tube sheets to withstand the corrosive action of the water. All steam from the boilers is condensed and returned to them. Practically all the heat needed for distillation is recovered. No cooling water is required and no operating difficulties were experienced since the installation of the new equipment.—INCO.

7.6.5

High Vacuum Technique—The Incurred Savings When Applied to Concentrations. E. J. KELLY. Carrier Corporation, Los Angeles, California. Paper, French Lick Meeting, American Institute of Chemical Engineers, French Lick, Indiana, May 14, 1952.

Falling film evaporators are helping the chemical industry overcome corrosion and scaling problems during concentration operations. The falling film evaporator, concentrates liquids by dropping a thin sheet or film of material down the inside of large diameter tubes which are heated from the outside. The water vapor is removed from the liquid in a separate condenser. The nature of the process is such that lower temperatures can be used in evaporation, thereby reducing corrosion of metals. Data is shown on the corrosion of mild steel by a salt solution in which the rate of corrosion was reduced 75 percent by the reduction of evaporation temperatures from 60° C. to 20° C. Since the falling film equipment works under a partial vacuum, temperatures are less for a given liquid than they would be if the evaporation were carried on at atmospheric or increased pressures.

Another factor in preventing corrosion of metals is the reduction of the velocity of the treated liquors in passing through the evaporation tubes. Forced circulation through evaporators is one way of reducing the capital cost of equipment, and transfer surfaces, and of increasing heat transfer. However, increased velocities also speed up corrosion rates. Kelly was successful in obtaining another 75 percent reduction in corrosion rates by decreasing the velocity of circulating liquor from nine feet a second to three feet a second. Another advantage cited by the author was the better structural properties of certain materials at lower temperatures. Chemical lead will have an 80 percent increase in allowable fibre stress when decreasing temperatures from 130° C. to 40° C.

A final advantage of the falling film concentrator is decreased formation of scale. Scale on the inside of heat transfer tubes materially cuts down the efficiency of the operation. Since most of the scale forming liquids have inverted solubility curves more scale forms at higher temperatures than at lower. The lower temperature of the operation will keep more material in solution and form less scale.

7.7 Electrical, Telephone and Radio

7.7, 3.4.9

Heat Pump Protects Underground Electric Cables Against Corrosion. ARTHUR J. HESS. *Heating, Piping and Air Conditioning,* **23,** 98-99 (1951) Feb.

Replacement of underground electric cables became an important item of maintenance expense after but a year of operation at an automobile plant. The trouble was caused by deterioration of the cable sheathing due to moisture condensed from outdoor air pulled into the relatively cool cableways. The problem was solved by use of a 5-hp. heat pump to provide warm, dry air forced into the cableway system.—BLR.

7.8 Wires and Cables Electrical

7.8, 3.5.8

Corrosion Fatigue of Wire Rope. H. ALTPETER. *Glueckauf,* **72** (1936).

Destruction of wire rope owing to fatigue followed by corrosion. Bending fatigue testers. Exclusive of access of oxygen to rope. Factors important in evaluation of performance of materials being tested for fatigue strength. Behavior of galvanized wire in moist air or salt-bearing air. Internal corrosion in ropes made of bare wire vs. ropes of galvanized wire. Importance of construction of rope.

Translation available Henry Brutcher, Box 157, Altadena, Calif.

8. INDUSTRIES

8.1 Group 1

8.1.2, 6.2.5

Stainless Jackets for Cold Water Exterior Risers. *Sheet Metal Workers,* **42,** No. 2, 44-46 (1950) Nov.

Air conditioning risers placed on the exterior of a building on New York's Herald Square, are encased in stainless steel columns for protection. A total of 16,792 lbs. of 12 ga., 18-8 stainless will go into the job and the estimated weight of all stainless, including runners, clips and fasteners is 23,000 lbs.—INCO.

8.2 Group 2

8.2.2, 4.2.1, 4.5.1

Corrosion Problems in Rural Power Distribution. ORVILLE W. ZASTROW, Rural Electrification Administration, U. S. Department of Agriculture. Paper, 7th Ann. Conf. Natl. Assoc. Corrosion Engrs., New York, N. Y., March 13-16, 1951. *Corrosion,* **7,** No. 9, 308-311 (1951) Sept.

Large scale construction of rural electric distribution lines in almost all parts of the United States has given rise to a variety of corrosion problems. Some are the result of special local conditions, while others are related to changes that came about when lines were designed for rural rather than urban construction. The corrosion problems are complicated by a wide range of atmospheric and soil conditions and by the difficulty of observing some kinds of damage before failure occurs.

On multigrounded wye distribution lines all underground metal parts are generally connected to a common system neutral conductor in order to maintain the lowest ground resistance possible. Underground corrosion has been excessive in some locations because of galvanic action between metal surfaces that assume varying potentials with respect to the soil.

Atmospheric corrosion problems in pole line hardware are characterized by replacement costs that are very high compared with the value of the items replaced and by questions of choice of materials and coatings for a wide range

of atmospheric conditions. High strength primary conductors, widely used in rural construction, depend on steel for strength while aluminum or copper provide electrical conductivity. These composite conductors have performed well in most atmospheres but corrode excessively under certain conditions.

Durability of transformer paints is being examined with the object of increasing the useful life of the coatings, as transformers represent a large item in the cost of a distribution system. The cost of maintenance painting of distribution transformers is so high that the economy of repainting small transformers is questionable unless they have been removed from service for other reasons.

8.9 Group 9

8.9.4, 6.2.1, 6.3.1, 2.2.4

Report of Committee 13; Application of Corrosion-Resisting Materials to Railroad Electrical Construction. Assn. of American Railroads, Washington, D. C. Report of Committees, 1947, p. 28-37.

Corrosion-resistant ferrous and nonferrous alloys intended for railroad electrical applications, such as overhead catenary constructions and wire crossings, were exposed: 1) to accelerated corrosion in the smoke jack of an engine house for 1-3 yr., 2) over a track near salt water under average corrosive conditions for 8-11 yr., and 3) in a railroad tunnel over the center of the track for 5-8 yr. The tunnel represents about the most severe corrosive conditions on a railroad using steam locomotives.

Materials with relatively good corrosion resistance in the accelerated smoke jack test generally gave good results in the service tests in the tunnel and near salt water; however, it seems impossible to predict accurately the loss of various materials in service from their behavior in the accelerated test.

Strand samples of hard-drawn copper and of various bronzes were generally the most resistant. Round samples of cast 18-8 chromium-nickel stainless steels and strand samples of the 18-8 stainless steel containing 2.5 percent molybdenum were satisfactory. Buffing of 18-8 steel rounds apparently increased the corrosion resistance.

Wrought iron had the greatest loss of weight of all samples. Large losses were also recorded for aluminum alloys and for low carbon steel. Malleable iron and a copper bearing steel were somewhat better than low carbon steel. Exposure to locomotive smoke results in a short life for: 1) brasses containing more than 20 percent zinc and 2) galvanized or copper plated steel. Steel wires protected by copper tapes and a steel core under copper wires were rusted, although the copper was unattacked. Asphalt paint did not prevent the corrosion of copper-plated steel strand, but a strand of seven copper-covered steel wires surrounded by twelve copper wires was in good condition.

Test results should be applicable to overhead bridges subjected to the direct blast of steam locomotives.—PDA.

8.10 Group 10

8.10.2, 6.3.6, 5.9.2

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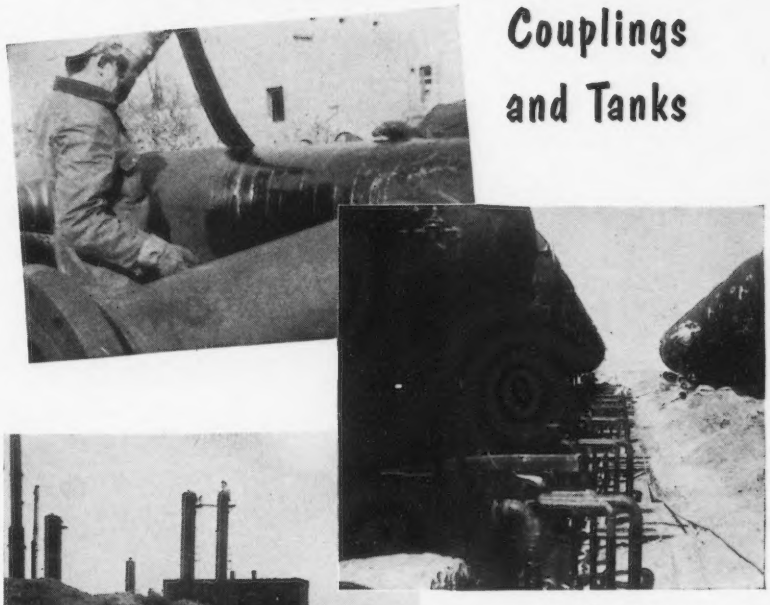

*Reg. U. S. Pat. Off.

Underground or above ground, TAPECOAT withstands severe corrosive attack. Over the past 11 years, this original coal tar protection in handy tape form has proved its dependability in guarding against moisture, acids, alkalis, chemical fumes and other severe conditions. As your first line of defense, TAPECOAT assures greater protection, reduces maintenance and cuts pipe replacement cost.

TAPECOAT is quick and easy to apply with the use of a torch to bleed the coating and insure a perfect bond. It is sized to the job in widths of 2″, 3″, 4″, 6″, 18″ and 24″. Wrapping is done spirally with widths up to 6″, and "cigarette-wrapped" in the larger sizes.

Write for full details and prices.

The TAPECOAT Company

Originators of Coal Tar Tape Protection

1521 LYONS STREET, EVANSTON, ILLINOIS

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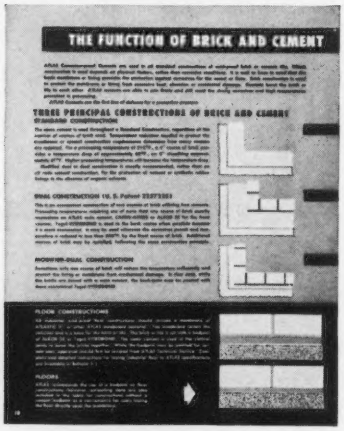
. . . a practical guide to Corrosion-proof cements

NEW, INFORMATIVE BULLETIN AVAILABLE WITHOUT OBLIGATION


THE FUNCTION OF BRICK AND CEMENT
THREE PRINCIPAL CONSTRUCTIONS OF BRICK AND CEMENT
STANDARD CONSTRUCTION
DUAL CONSTRUCTION (U. S. Patent 2327333)
MODIFIED-DUAL CONSTRUCTION
FLOOR CONSTRUCTIONS

HERE in concise form you will find complete data on the basic types of corrosion-proof cements and constructions. Each cement is graphically shown in its relationship to temperature and the broad classes of corrosives handled.

In addition, RESISTANCE TABLES are included which cover 176 common corrosives, and relate them to cements satisfactory for that service. And, ESTIMATING TABLES guide you in figuring not only cement, but also brick requirements for most corrosion-proof construction jobs.

SEND FOR YOUR COPY OF BULLETIN 5-2 TODAY

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ATLAS PRODUCTS STAND . . . between your process and corrosion.

***Corrosion-proof:* Cements . . . Coatings . . . Linings**

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MULVEY. *J. Inst. Metals*, **77**, Part 5, 357-388 (1950) July.

A detailed description is given of a recently installed continuous plant in an American brass mill. Metal melted in 1000-kw. Ajax-Scomet induction furnaces is cast into 2000-lb. slabs in a continuous-casting machine of the Junghans-Rossi type. The 2¼-in.-thick slabs are broken down in a large two-high cold-rolling mill and, after annealing, the rolling is completed, with more annealing, in two four-high mills. Annealing is carried out in four continuous, roller-hearth, propane-fired furnaces equipped with spray-cooling chambers. Spray pickling in acid bichromate solution is effected in two machines capable of handling brass strip 29-in. wide at rates up to 600 fpm. Finally, the wide strip is slit on one of three machines, depending on its thickness, and inspected on both sides at a rate of 60-240 fpm. Vacuum-handling equipment is extensively used in the plant.—TDD.

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20 YEARS is a long time on the job, preventing corrosion damage to underground pipe. SOMASTIC Pipe Coating has furnished complete protection at severely corrosive locations since its first year—1930.

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SOMASTIC IS The Best PIPE COATING

2 ECONOMICAL METHODS OF APPLICATION:

... by Central Plant
... by portable Railhead Plant

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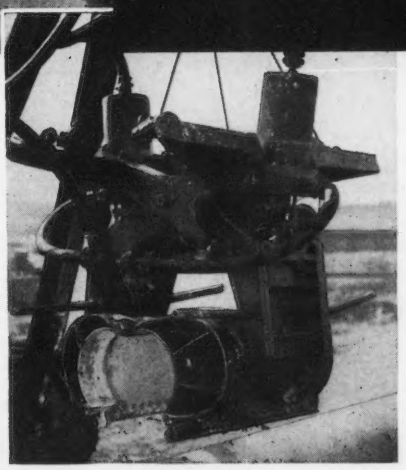

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Isn't it logical that factory-coated pipe should last longer? As a final precaution, every length of pipe protected by Hill, Hubbell is inspected with electronic holiday detectors before leaving the factory.

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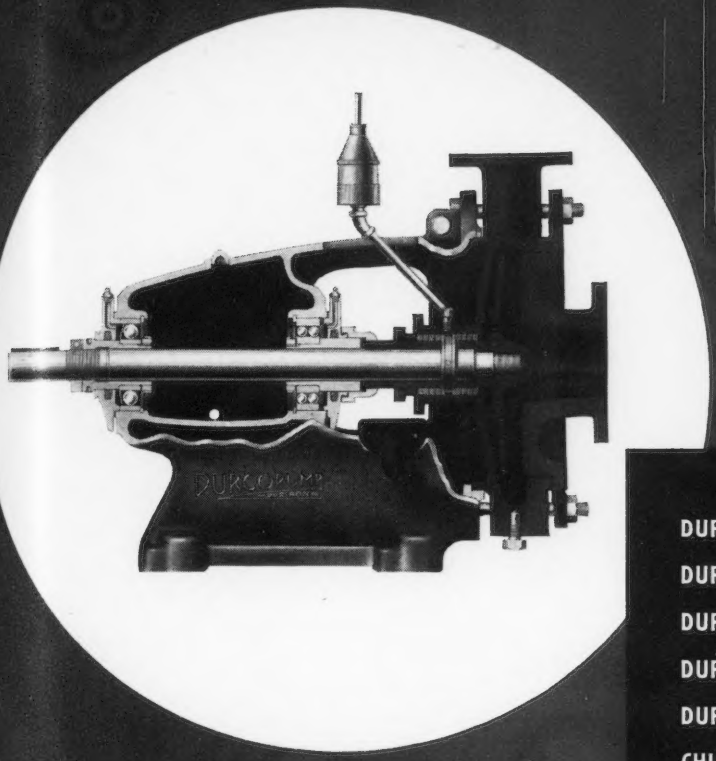

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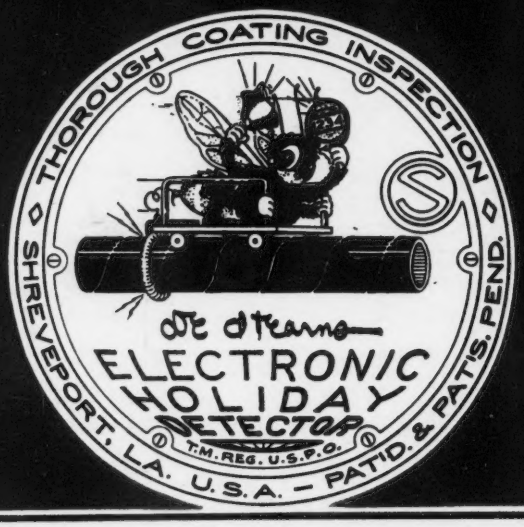

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